Planetary Knowledge: Shifting from Social to Planetary Studies of Scientific Knowledge

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Abstract

Based on a review of literature on the notion of the planetary, the concept of planetary scientific knowledge is developed. It reframes scientific knowledge as integrally and inherently planetary. While building on the established understanding in Science and Technology Studies (STS) of scientific knowledge as socio-material, the planetary perspective introduces a new conceptualisation of scientific knowledge as extended relations in and through one shared world. The notion of planetary scientific knowledge parts with problematic underpinnings of modern science, from widening metabolic rifts to obscured accountability. Planetary scientific knowledge is transgressive, and in its spherical ontology it grants agency to scientific knowledge to intervene in its own means of production. This implies heterogeneous, changing relations and multiple temporalities. The concept of planetary scientific knowledge thus offers a foundation for a move from social to planetary studies of scientific knowledge.

Keywords: Anthropocene, Capitalism, Decoloniality, Digitisation, Globalisation, Ontology

Introduction

There is a growing concern in science about the Anthropocene, climate change and the state of the planet. At the same time, however, scientific knowledge increasingly relies on material extraction and on growing energy consumption, which add to climate change and negatively affect the state of the planet[1]. This article is motivated by the paradox between the increased concern about climate change and the growing contribution to climate change through science. While universities and funding organisations have started attending to questions of sustainable science, particularly with a view to decreasing their energy costs (e.g. Fissi et al., 2021; Freese et al., 2024; Lannelongue, 2021; Pasek & Sutherland, in this issue; Sen et al., 2021; Woolston, 2024), there is a need for more conceptual discussions of scientific knowledge having planetary repercussions. In this article,

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we develop the concept of 'planetary scientific knowledge,' which, beyond questions of how to save energy in science, recycle and use fewer materials, etc., addresses the consequences of understanding scientific knowledge as a planetary phenomenon.

Our argument builds on STS conceptual frameworks of socio-material knowledge and discusses how the notion of planetary scientific knowledge extends analytic attention beyond social and material entanglements. STS scholars have conceptualised socio-material knowledge in different ways, including in material-semiotic (e.g. Law, 2008), hybrid (e.g. Latour, 1993) and epistemic-ontic manners (Verran, 2001). Also, the ontological turn within STS can be seen as a further development of concepts of socio-material knowledge (e.g. Sørensen, 2007; 2009; Woolgar & Lezaun, 2013). These discussions have qualified and consolidated the idea in STS that knowledge is socio-material. They underline the performative socio-material effects of knowledge, in addition to focusing on how knowledge represents certain phenomena or events. Questions of how scientific knowledge in terms of facts and expertise *about* the planet – such as climate science – comes to have effects on politics and society have been detailed in numerous publications in STS (e.g. Edwards, 2013; Gabrys, 2016; Jasanoff & Martello, 2004; Knox, 2020; Latour, 2018; Sandbach, 1978; Silke et al., 2016; Watts, 2018). In this paper, however, we address the very ontology of scientific knowledge and how to conceptualise it as planetary.

Laboratory studies have famously shown that scientific knowledge is produced through technical and often industrial apparatuses. The concept of planetary knowledge extends this conceptualisation by, first, including the materials involved in producing these apparatuses, which are extracted from the planet. Scientific apparatuses, as well as experiments, scientific equipment and mobility, furthermore, consume energy and matter that are also channelled through planetary processes. Introducing the notion of planetary knowledge does not just add more materials and processes to social studies of scientific knowledge. It is, also, about re-conceptualising scientific knowledge. In this article, we focus attention on the conceptual consequences of understanding scientific knowledge as planetary. We do so through a review of how certain scholars (e.g. Chakrabarty, 2009; Danowski & Viveiros de Castro, 2017; Haraway, 2016; Latour, 2017, 2018; Marx, 1969[1865]; Saitō, 2017; Spivak, 1999, 2003, 2012; Stengers, 2015; Tsing, 2015) have been thinking about the term 'planetary,' and we draw on this review to re-conceptualise scientific knowledge. The contribution, thereby, points to planetary scientific knowledge as characterised by 'extended relations' in and through 'one shared world.'

The characteristic *extended relations* of planetary scientific knowledge imply the transgression of set categories, structures and ontologies; they point to the agency of scientific knowledge to intervene not only in practices, where knowledge circulates, but in scientific knowledge's own means of production. They include attention to the heterogeneous and changing relations across the extended relations of scientific knowledge and they address multiple temporalities. We furthermore develop the characteristic of extended relations of scientific knowledge as unfolding in and through 'one shared world' by arguing that extended relations are rendered spherical rather than expanding flatly on one plane; that the planetary acts through its components; that the extended relations emphasise connectedness and not totality; that processes are always shared somewhere, somehow; and that extended relations have consequences rather than limits.

In what follows, we begin with a section discussing key aspects of STS understandings of scientific knowledge as socio-material. Following this, we review current literature on the notion of the planetary to develop and specify this term to think about scientific knowledge. In a third step, we inquire how the concept of scientific knowledge alters when thought of as planetary, just as we discuss the limitations of the term. The conclusion proposes a move from social studies of scientific knowledge to planetary studies of scientific knowledge and discusses the differences between the two.

Socio-material scientific knowledge in STS

Scientific knowledge is not only mental; it is also social, and material. It is not simply a product of

individual thought or genius inventors; it is produced through social relations, including material apparatuses. These are foundational insights of STS. Bloor (1999: 82) maintains that,

> [l]ike Karl Mannheim before him, and many others since, Merton felt that sociological enquiry into the nature of knowledge was … confined to offering a description of the conditions encouraging or inhibiting the growth of science.

In contrast to Mannheim and Merton, early scholars of STS saw the ability to describe and analyse the 'nature' of knowledge – or indeed its ontology – as being key to the field. This ability is not only a question of analytical skill, but also a moral and political commitment to challenge mentalist, individualist, and idealist understandings of knowledge often encountered in so-called herostories. As Kuhn (1962) had emphasised before Bloor, the study of the 'nature' of scientific knowledge meant that the question of truth, which is a pivotal interest of epistemology, became replaced in social studies of scientific knowledge by the question of which knowledge is successful and prevails over other knowledges. Thus, the question of power entered into the study of scientific knowledge. Different directions were taken in STS concerning the conception of socio-material scientific knowledge. We follow the so-called ontological line, which points to scientific knowledge as inseparable from its socio-material enactment (e.g. Law, 2002; Mol, 2002). Garfinkel, Livingston and Lynch's (1981) conversation analysis of the discovery of the Independent Galilean Pulsar[2] (IGP) was an important early study to emphasise the social, material and practical aspects of scientific knowledge. They showed how the IGP as a material object, the social practice of producing it, and the knowledge of it, became intimately entangled through the process of scientific knowledge production. This study was just one of the many analyses in STS that shaped an understanding of scientific knowledge as inseparable from its material and social process of production. Importantly, the authors state that the knowledge *of* the IGP – not *about* the IGP (Garfinkel et al., 1981: 132–133) – was social and material, construed out of the laboratory activities. This trope indicates that the scientific knowledge produced is not different from the production itself. We shall return to this below when discussing the ontology of scientific knowledge.

The laboratory studies (e.g. Knorr-Cetina, 2003; Latour & Woolgar, 1979; Livingston, 1986; Lynch, 1985; Traweek, 1988) consolidated the groundwork for this new conception of scientific knowledge as practical, social and material, and established ethnography as the method of choice to study scientific knowledge. The methodological intervention towards observing 'science in action' (Latour, 1987) and the accompanying re-conceptualisation of scientific knowledge as ontologically social and material did not only reveal new empirical insights about science, it also opened the 'black box' of science to non-scientists and allowed them to form their own – and often different – perspectives on science, independent of the views of scientists. With the conception of scientific knowledge as socio-materially and practically produced, STS gained a new language to speak about science, which made power not only a question of which scientific knowledge prevails, as discussed above; it also challenged the question of the ownership of scientific knowledge and who is granted the right to speak in the name of science.

After the laboratory studies and the emergence of actor-network theory (ANT) followed controversies in STS and beyond about the ontology of scientific knowledge, i.e., about the nature of existence or being of scientific knowledge, about what knowledge is (cf. Law, 2002). These debates primarily concerned the 'general symmetry principle' (Latour, 1999a) and the question of the agency of non-humans in the production of scientific knowledge.[3] Latour (2005) and Law (2008), among others, emphasised that this principle does not regard humans and things as equal, but enables a methodology to observe the distribution of agency among the heterogeneous components involved in creating scientific knowledge.

Moreover, the approach to scientific knowledge as socio-material points to knowledges in the plural of which scientific knowledge is but one kind (and indeed, in itself heterogeneous and embracing many knowledges (Barry & Born, 2013). Scholars of feminist and post-colonial epistemologies have contributed crucially to

this view of socio-material scientific knowledge. As a leading figure in both feminist and post-colonial STS, Harding (1991, 2011) emphasises how researchers' socially and materially shaped, gendered and racialised standpoints condition the knowledge that can possibly be produced. Mol (2002) turned this into not only a question of a plurality of perspectives, but a matter of the multiplicity of materiality – in her case of the body. She discussed the body as having different socio-material constitutions, while remaining one single body, in and through which these socio-material constitutions come together. Analogous to how Mol theorises the body (and later also theory; see Mol, 2021), we can think of scientific knowledge as consisting of multiple translations of a phenomenon combined into one knowledge. Scientific socio-material knowledge is thus in itself multiple and contains tensions.

Importantly, the concept of scientific knowledge as socio-materially and practically constituted also implies its continuous production and maintenance. New materialist thinking has emphasised this aptly with the notion of 'intra-action.' Barad (2007) shows how material bodies and their norms and deviations are continuously re-done through practical entanglements of bodily action and material apparatus, whereby being, knowing and ethics become inseparable matters, where "[k]nowing is a material practice of engagement as part of the world in its differential becoming" (Barad, 2007: 89).

In summary, we draw on a conception of socio-material scientific knowledge in STS that points to an engagement with the practical ontology of such knowledge; that is, with the way scientific knowledge is enacted in and through socio-mate-

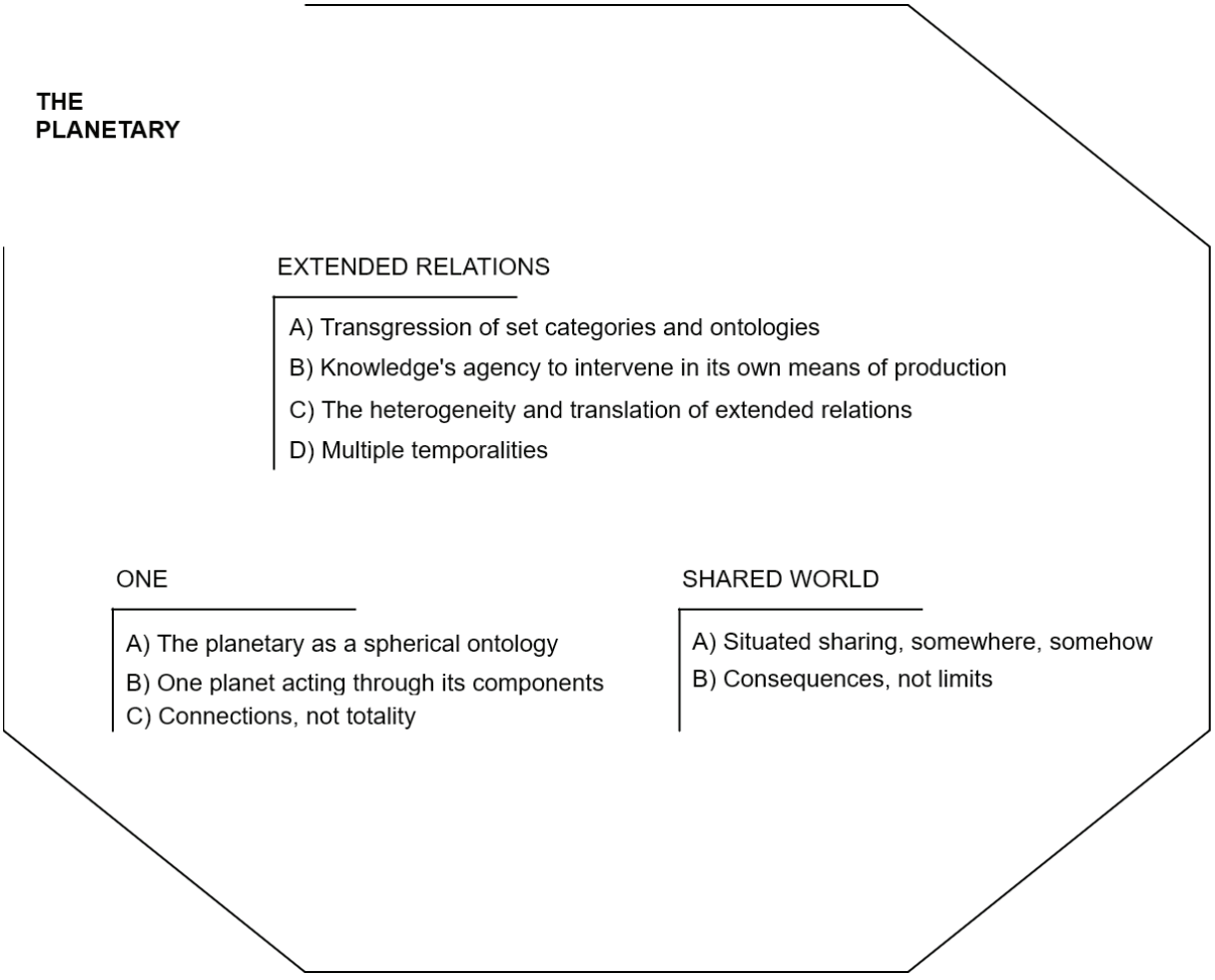

Figure 1 A schematic overview of the concept of the planetary defined as 'extended relations' in and through 'one shared world,' and the key aspects of these two dimensions.

rial practices (cf. Woolgar & Lezaun, 2013). This ontological shift in the conceptualisation of scientific knowledge has had extensive consequences, not only for approaches to the study of scientific knowledge, but also and regarding the societal and political, the local and trans-local status of scientific knowledge, including in STS itself.

The planetary term

In their proposal of a 'planetary turn,' Elias and Moraru (2015) point to a planetary analytic that consists of a conceptual trinity: a) the 'planet' marks a shared ecological habitat and interdependencies of actors and actions near and far; b) 'planetarities' are different modes of performing and living through planetary relations; while c) 'planetarisation' is the ethical practice of making precarious planetary relations visible and discussable. We propose the complementary concept of 'planetary scientific knowledge,' comparable to how STS has developed its understanding of scientific knowledge as ontologically socio-material. Socio-material scientific knowledge is not a specific empirically identifiable kind of scientific knowledge that is different from other kinds of scientific knowledge. Rather, the notion of the socio-material points to a particular conceptualisation of the ontology of scientific knowledge, and accordingly, to specific analytical strategies. Similarly, the 'planetary' serves as an additional specification of both the ontology and analytics of socio-material scientific knowledge.

In what follows, we develop the notion of the planetary as an analytical device that contains the two dimensions 'extended relations' and 'one shared world.' Each of these dimensions is explained below, highlighting their main aspects, as outlined in Figure 1. Our conceptualisation of these two dimensions builds on current literature that explicitly discusses the notion of the planetary as well as on work that engages with related terms, such as the Anthropocene, Capitalocene, Gaia, Chthulucene, and Terrapolis.

Extended relations

The aspect of extended relations of planetary knowledge implies: a) the transgression of set categories, structures and ontologies; b) granting agency to knowledge to intervene in its means of production; c) heterogeneous and changing relations; and d) multiple temporalities.

Transgression of disciplinary categories and ontologies

The first characteristic of the planetary as extended relations is that it implies relations that cross and challenge material and epistemic boundaries, and draws attention to relations that lie between, within and beyond settled categories, structures and practices. Extended planetary relations are partly a result of physical extension. Characteristic to processes and events that are considered planetary, such as climate change or pandemics, however, is that they disrespect pre-defined boundaries, such as geographical, categorical, and ontological ones (cf. Blake & Gilman, 2024): viruses and CO_2 travel across national boundaries regardless of increased border control and environmental regulations; air pollution may be chemical in origin, but quickly transgresses the disciplinary boundaries and turns into social and biological issues (Liboiron, 2021). These examples and the understanding of the planetary term as extended relations draw on post-colonial scholarship pointing to the need to exceed binary Western categories of nature and culture and to rethink multispecies entanglements (e.g. Chakrabarty, 2009; Danowski & Viveiros de Castro, 2017). By foregrounding an incurable 'metabolic rift' already identified by Marx and Engels, ecological socialism highlights how capitalism systematically disrupts the exchange between humans and nature (Burkett & Foster, 2006). The blurring of human-nature boundaries is a deeply material affair, for example when extractivism depletes planetary capacities for reproduction, and due to waste practices that are materially not external to, but integral to, the planetary system (Greeson et al., 2020). The notion of extended relations as an aspect of the planetary notion stresses the inclusion of such processes in planetary analytics. It includes capital's circuits that are inextricably linked with natural processes and bind ecological processes to social inequalities. Tsing and colleagues (2017) revive the metaphor of 'monsters' (cf. Law, 1990) to generate a sensitivity to the 'promiscuous' and heterogeneous entanglements

of extended planetary relations. These are monstrous both in terms of scarring and deteriorating purified modern Western thought and capitalist practices.

Knowledge's agency to intervene in its own means of production

The second characteristic of the planetary as extended relations implies granting scientific knowledge the agency and accountability to intervene in its own means of production. Planetary scientific knowledge's transgressive nature gives knowledge an agency distinct from that assigned in modern technosciences, where scientific knowledge is seen as external to entities within passive environments. The imagined passivity of the object of knowledge and the object's distance to the knowledge that is 'about it' also renders knowledge itself passive. Thus purified (Latour, 1993, 1999b), technoscientific knowledge is considered lacking agency to intervene in the materials, energy and other matters mobilised for its generation.

The agency of human scientists and their intervention in social and biological lives is addressed by scientific ethics, but here, scientific knowledge is acquitted from accountability for how its own means of production and production processes are potentially harmful to planetary relations. The scientific practices' extractive, exploitative and polluting effects are mostly made invisible in the technosciences, and such effects are a priori excluded from their specialised and thus narrow areas of accountability (cf. Liboiron, 2021; Maguire, 2026; Stengers, 2018). This critical research reminds us that the planetary, as an analytical term, must be sensitive towards the agency of scientific knowledge that extends into its means of production.

The heterogeneity and translation of extended relations

The third point about the planetary as extended relations is that the planetary draws attention to scientific knowledge's heterogeneous and changing relations.

Conceptualising planetary scientific knowledge as extended relations differs from ideas of globalised science. Many authors explicitly suggest the notion of the planetary (or similar) as a critique of globalisation, given the specific economic, political, social and indeed anthropocentric rationality of the latter, and its exclusion of non-human agents (Clark & Szerszynski, 2021; Elias & Moraru, 2015). Spivak (2003) famously proposed "the planet to overwrite the globe," criticising that "[g]lobalisation is the imposition of the same system everywhere" (72). We are, she writes, "planetary creatures rather than global entities" (Spivak, 2015: 292). Similarly, Tsing (2004) asserts that the trope of scaling comes with a logic of expansion without changing the frame. We build on these critical engagements with globalisation and scaling and hold that the heterogenous extensions of relations as an aspect of the planetary implies that extension comes with ongoing changes and translations of assembling and disassembling (Greeson et al., 2020; Latour, 1999b). Extensions are furthermore selective – when some relations extend, others are cut (cf. Strathern, 1996).

Multiple temporalities

The fourth characteristic of the planetary in terms of extended relations points to extensions both in space and in time; to the generation of histories and futures; and to both acceleration and slowing down. Many authors point to the planetary as more than spatial. Haraway (2016) defines what she calls 'terrapolis' as an *n*-dimensional space made up not only of the three Euclidean dimensions, but also of stories, memories, practices, multiple species, and more. Several scholars emphasise in particular the temporal quality of extended planetary relations. Developing what they call 'planetary social thought,' Clark and Szerszynski (2021; cf. Hanusch et al., 2021) note that planetary relations continuously change, while Elias and Moraru (2015) emphasise the acceleration of changing relations. Planetary relations do not simply extend in space; they also transform over time. Importantly, the attention to acceleration (cf. Felt, 2025) should not overshadow planetary transitions that are slow, sometimes too slow for humans to grasp (Nixon, 2011). Beyond this processual consideration of the changing and rhythmic character of extended planetary relations, Chakrabarty (2009) and Danowski and Viveiros de Castro (2017) argue

that planetary relations involve history in terms of layers and foldings of historical processes. The problems we must deal with, Danowski and Viveiros de Castro maintain, are not in the future, they are in the past. The authors draw attention to how the Anthropocene – to the surprise and challenge of modern thought – has revealed that the evolution of species and the history of capitalism are deeply interwoven. On the one hand, pasts need to be reconstituted, and on the other, the idea of history as past no longer holds up (if it ever did). Again, Tsing and colleagues (2017) offer a figure to think about extended relations as also temporal: The 'ghost' is a creature from the past that nonetheless has agency in the present.

Conceptually, the planetary also addresses futures. Pels (2015) points to what he calls the 'open future' of modernity, which comes with the idea that any line of development is at any time possible and available to the individual to assess and choose which one to take. In the Anthropocene, future presents itself differently, accompanied by an image of the future of the planet and its inhabitants as in many ways already laid out and considerably constrained. Pels reminds us that key to the generation of the open future was the violent emptying of the American frontier of Native Americans, and that for one future to open up, another may have to be limited, emptied or closed down.

To sum up, the notion of the planetary as extended relations creates sensitivity to boundary-crossing relations extending across categories and ontologies, and it grants knowledge agency to intervene in its own means of production. Furthermore, planetary extended relations draw attention to how relations are heterogeneous and translate as they extend, just as they imply multiple temporalities.

One shared world

Chakrabarty (2009) observes that a human collective has arisen from a shared sense of catastrophe when confronted with climate change. Similarly, Latour (2017) notes that the Anthropocene renders humanity a whole and a single unit. In this section, we critically discuss the planetary as collectifying, unifying or holistic. We bring these thoughts together in the notion of 'one shared world,' addressing first the 'one,' which we explain through three characteristics, and then the 'shared' through two further characteristics (see Figure 1). The 'one' of one shared world is: a) rendered spherical through extended relations bending and turning, not leaving behind what came before, but including it and returning to it; b) the 'one' of the planetary is also defined by the understanding that entities enmeshed with planetary relations – such as scientific knowledge – are not components on the planet, but on the contrary, that the one planet acts through these entities; c) the 'one' of extended relations emphasises connectedness, not totality. The planetary as one 'shared' world additionally points to: a) processes always being shared somewhere, somehow; and to b) consequences rather than limits.

The planetary as spherical ontology

As a first point about the planetary as one shared world we emphasise that extended relations do not expand endlessly on a flat plane, but bend and fold in a spherical space, and return to their point of departure, rendering the planetary 'one.' Different from the flat ontology of actor-network theory (cf. Marston et al., 2005), which generates an image of relations expanding endlessly in all directions, Mol (2021) and Saitō (2017) have recently pointed to the physiological and chemical metaphor of 'metabolism' as a fruitful figure of thought. According to ecological socialism (Burkett & Foster, 2006), Marx adopted the term to think of natural and social processes as an extensive organic whole. He emphasised that the term grants nature a significant position for resisting capital: capital cannot endlessly exploit nature for maximum profit, since while attempting to dominate nature, capital inevitably undermines the foundational material conditions for human – and eventually its own – development. Metabolism is different from the imaginary of a flat ontology of endlessly expanding networks, which never bend, but move ahead, away from its point of departure. It is a circular system in which consequences of action return to their sources, where actions and consequences are of the same process, with digressions and translations included. Excess and spillover are inherent to metabolic circles. The metabolic rift means increased entropy. Bluntly

put, when generated through data practices and run via data centres, scientific knowledge is an extended translated relation of fossil energy, which eventually may undermine the foundation for producing scientific knowledge (cf. Pasquinelli, 2017; Rubio et al., 2025). Thinking with the spherical figure of the planetary term suggests a 'spherical ontology' replacing actor-network theory's flat ontology, and emphasises that any extension will eventually return to its point of departure, which, as discussed above, will however be translated and changed. The spherical ontology renders the planetary 'one.'

One planet acting through its components

The second characteristic of the planetary as 'one' shared world points to all planetary beings as interdependent, and consequently there is no outsourcing, no resort to escape effects of planetary processes nor to act in isolation. Post-colonial thinkers have offered diverse ways of thinking about the planetary as one shared world. Viveiros de Castro (2004) points to universal humanity, which we consider a version of what we call one shared world. He explains that in Amerindian animist cosmology animals are transformations of a primordial universal humanity. Different from a Western cosmology in which humans are transformed animals, animals are transformed humans to Amerindians, and nonetheless still humans. To Amerindians, things and beings generally originate as a transformation of something else – akin to how Westerners think of energy. This cosmology of transformation is another way of conceiving the planetary as one shared world. While this is only one possible way of conceptualising how the planet acts through its components, we take it as inspiration to maintain that the 'one' of the planetary implies that all that is planetary is conjoined – either as metabolic, acting through organisms, or as transformations of a shared universal.

Connections, not totality

The third characteristic of the planetary as 'one' shared world emphasises that the planetary as 'one' implies connectedness, not totality. The conceptualisation of the planetary as one shared world may be misunderstood and associated with the controversial notions of containers (Law, 2015), 'one-worldism' (Young, 2021), holism (cf. Bubandt & Otto, 2010), the 'blue marble' imaginary[4] (Poole, 2008), or totalitarianism (Yusoff, 2018), among others. Critical literature on the concept of the Anthropocene (and Capitalocene, etc.) conveys the argument against a totalising concept of the planetary (Haraway, 2016; Howe & Pandian, 2020; Omura et al., 2021; Tsing et al., 2017).[5] Elias and Moraru (2015: 22) argue sensibly that it is analytically possible – and desirable – to grasp the planet as a whole, while keeping in mind that no "reference t[o] the dynamics of the entire 'world-system'" can afford to lose sight of the complexities, contradictions, and other non-systemic features. Similarly, Latour (2017: 130) formulates the caveat that,

> [w]hether we are dealing with the idea of the Anthropocene, the theory of Gaia, the notion of a historical actor such as Humanity, or Nature taken as a whole, the danger is always the same… [to authorise] a premature leap to a higher level by confusing the figures of connection with those of totality.

Until now, we have focused on the 'one' of one shared world and proposed that the 'one' implies: a) a conception of relations as extending in spherical space; and b) that the planetary acts through its components. We have furthermore c) carefully differentiated between 'one' shared world and totalising singularity. We now move from focussing on the 'one' to the aspect of the 'shared' of one shared world.

Situated sharing somewhere, somehow

The first point about the planetary as a 'shared' world draws attention to multiple, situated planetary processes always shared somewhere, somehow. To 'share' is a curious word that ambiguously suggests that a shared world is made up of various parts that are divided among those who are sharing, and that the shared world at the same time is one common whole.[6] In the sense of one shared world, the planetary is simultaneously whole and divided; it is multiple (cf. Mol, 2002).

Schroer (2022) emphasises the need for a vocabulary of the Earth that involves all living beings and their diverse encounters; not only highlighting cooperation but forcefully including

conflicts. The notion of 'shared' grounds the concept of the planetary by turning the perspective away from imagining extended relations placed in front of perceiving humans and towards a view from inside the relations thus shared. From such a perspective, Danowski and Viveiros de Castro (2017) note that climate change is experienced differently in different places. The sharing of the planetary does not constitute sameness. The planetary as one shared world implies turning thinking away from what Danowski and Viveiros de Castro (2017) call the Western cosmology's discontinuation of nature and culture, which is accompanied by a perspective on the planet as a world before us, a world-without-us, or a peopleless world. Differing from this perspective, the notion of the planetary points to a world-shared-among-us. It is in this context that anthropologists and STS scholars join forces with postcolonial ethnographic endeavours to draw attention to knowledges of Indigenous peoples, and also to experiences of non-human beings. Authors turn to animals, plants, microbes and embodiments of relations "to sound out the elusive depths of the worlds generated in complex, ceaseless, recursive movements between objects and their backgrounds" (Omura et al., 2021: 13). To share the planetary is thus to be situated within the planetary realm, experiencing and engaging particularly – i.e. partially – with a share of the planet. While sharing is often positively connoted, we have been careful to point to damages, conflicts and controversies. Also destruction and violence draw the involved together in relations of sharing – in such cases sharing their destructive or violent relations – although from different and probably opposing positions, possibilities and agencies.

Consequences, not limits

The second point about the planetary as a 'shared' world draws attention to the consequences of shaping shared relations. Spivak (2003) reminds us that sharing always has an object. Sharing means sharing something, which is outside of the one sharing. She calls it alterity: "[t]he planet is a species of alterity, belonging to another system, yet we inhabit it" (Spivak, 2003: 72). The planetary denotes the other to its share-holders, but nonetheless, it is where we live. Like Viveiros de Castro (2004), we emphasise that the collective 'we' of those sharing the planetary will not fully understand it and will not be able to control it; yet 'we' must live in and with the planetary. The situation of being part of a condition of damage and decay, and living with the resources at hand without prospect to progress or extension is described, among others, by Tsing (2015) as living in the ruins of capitalism; by Stengers (2023) as making a living in the ruins; and by Ureta (2021) as 'ruination science.' In addition, Jackson's (2014, 2023) 'broken-world thinking' resonates with this conceptualisation. Broken-world thinking changes the bearing of the planetary. It foregrounds maintenance and creative repair as alternatives or as complementary to a continuous search for new frontiers, new technical solutions or scientific progress that will allegedly solve the crisis. Spivak (2003) adds that being planetary means being 'on loan.' To be planetary is something that has been given to planetary creatures, and it will eventually be given back or taken away.

Ruins, broken worlds and alterity point to constraints. At least since the Club of Rome published their report *The Limits to Growth* (Meadows et al., 1972) – with a terrestrial globe replacing the "o" on the original book cover – the insight that the planetary implies limits has spread widely. Let us contemplate the notion of limits for a moment. A limit is a boundary to expansion, or to a quantity (e.g. of resources). In relation to the planetary, 'limit' emphasises that we can only burn so-and-so much fossil fuel, produce only a certain amount of toxins, work only so-and-so many hours, etc. It places the agent confronted with a limit in relation to that limit, yet external to it. Science-backed environmentalism often claims to identify the remaining limits of specific natural resources or ecosystems' capacities as if they existed 'out there,' say, counting down the minutes until a carbon budget is exhausted. Kallis (2019) cuts into this debate by showing that limits are not naturally given. They arise from social arrangements and the concrete relations of production (and more-than-human metabolisms) through which humans live and work. Liboiron (2021) adds that the very notion of limits stabilises industrial wasting practices by defining seemingly inconse-

quential 'threshold' values and, in turn, destabilises other, more ethical practices.

Haraway's (2016) emphasis on 'living in consequence' as an aspect of 'response-ability' offers a concept to think in other directions than limits. Although they both imply constraints, living in consequence is not the same as having limits. 'Limit' connotes quantity (or lack of quantity) while 'consequence' indicates a register of quality. Hence, limit and consequence evoke different agencies. Limit points to using less; consequence points to responding to the relation in which one is entangled. Importantly, Haraway emphasises that we are not all response-able in the same way. Conceptualising the planetary as sharing does not imply that all hold the same capacities to respond to planetary entanglements. Ecological interventions pose issues of justice, as among others Papadopoulos et al. (2023) emphasise. All planetary creatures share the planetary relations, but we do not all have the same share in the planetary.

In this section, we have discussed how to think about the planetary as 'one shared world,' a conceptualisation that is recognisable in much of STS literature on climate change, the Anthropocene and related issues. We have discussed the reservations and critiques of unifying holistic and totalising understandings of the planetary, and have emphasised an understanding of the 'one' world as a matter of a spherical, relationist thinking and of interdependencies and connectedness. We have finally explained how a 'shared' world is key to the planetary notion in terms of drawing attention to partial and situated processes, and to living in consequence.

Discussion: Planetary scientific knowledge

Above, we outlined how STS has developed a view on scientific knowledge as entangled with diverse socio-material components and processes. This section asks how to understand scientific knowledge if we add 'planetary' to the 'socio-material:' what does it mean that scientific knowledge is planetary? What is the ontology of planetary scientific knowledge? We thus develop a concept of scientific knowledge as planetary by analysing the implications of applying each of the dimensions of the planetary discussed above to the notion of scientific knowledge.

The idea of the planetary term draws attention to extended relations that cross and challenge pre-given boundaries. Applied to scientific knowledge, it suggests that extended relations of planetary matter extracted from the planet – including the efforts of humans, animals, plants, microbes, territories and other planetary matter – are components of and co-constitute scientific knowledge. Planetary scientific knowledge is understood as extended relations not only comprising humans and technologies involved in producing knowledge in academia and in circulating it throughout society, but involving also extractive energy and resource practices upon which the apparatuses of scientific knowledge depend, and which intervene into the constitution of the planet.

Thinking with the notion of the planetary furthermore points to the heterogeneous, translating and multispecies relations of scientific knowledge. Scientific super computers and high-performance and AI computing are good examples. The involved scientific apparatuses are the results of mining and semiconductor fabrication along with global transportation. Scientific competition and its dependency on always faster computing facilities at one location of the extended relations of planetary scientific knowledge is necessarily related to extractive processes of mining, chip production and energy consumption at another location of the scientific knowledge's extended relations, thus intervening in not only social and political orders, but also planetary landscapes and metabolisms. While the computation in the former location may seem harmless and inconsequential, these processes involve extractions and pollution at the latter location, which may leave "scars on the planet, hazardous waste, dangerous and unfair labor practices, ecological devastation, and more," as Hogan et al. (2022: 4) formulate. That scientific knowledge is tangled up with pollution, colonialism, destruction of habitats and violence against more- and other-than-human worlds has already been studied in STS (e.g. Liboiron, 2021). Historians of science have well documented how, already in the early days of modern science, scien-

tific knowledge was already dependent on global supply chains, colonial information orders and scientific knowledge claiming land (and entities residing) to generate knowledge. Schaffer (2009: 247) emphasises that there was "a link between the colonial information order and the empiricist knowledge regime of the late seventeenth century, between forms of epistemology, providentialism and domination." This analytical lens of global capitalism is helpful, too. It points to the capitalist forms of domination involved in scientific knowledge, as well as to the gradual erosion of regenerative capacities folded into these processes. The planetary concept here urges STS to investigate (and potentially challenge) the planet-making activities (Battistoni, 2025) in which scientific knowledge is involved. The notion of planetary scientific knowledge hence means not only understanding scientific knowledge as translated and shaped through socio-material and geo-political processes but also attending to how scientific knowledge is involved in shaping, and sometimes destroying, landscapes and living conditions.

The notion of the planetary emphasises both the spatial extensions of scientific knowledge's planetary relations, and their various temporalities. An illustrative example of how rhythms of scientific knowledge are entangled with planetary temporalities of mineral extraction is the difficult access to (rare) earths during the COVID-19 pandemic, which slowed down the production of computing components (Akcil et al., 2020; Ilankoon et al., 2022; Tooze, 2021). An additional effect was a reduction in the productivity of the sciences that were dependent on the supply of such components (Püttmann and Thomsen, 2024). Shortages in semiconductor supplies, too, delayed the acquisition of 'necessary' computing equipment and impeded data analysis and the progression of experiments in fields reliant on high-performance computing. Geological formations dating millions of years back and resulting in the Atacama Desert being the darkest place on Earth point to another planetary foundation for science, as the desert today serves as the preferred place for astronomic observations. Such planetary pasts are ghosts that actively interact with contemporary scientific knowledge (cf. Burrell, 2020). They underscore the many temporalities of planetary scientific knowledge (Tsing et al., 2017), and they invite STS to rethink the implications of speed, acceleration and slowing down of scientific knowledge (cf. Felt, 2025). The concept of planetary scientific knowledge points to how temporalities and rhythms of the planet are intimately related with those of science.

Learning from scholars of planetary relations, we emphasised the 'one' of the planetary and pointed to a move from flat to spherical ontology. Extended relations do not expand endlessly, but bend in spherical space, making them return to their point of departure. Paraphrasing what ecological socialism states about capital and applying the idea of the entanglement of capital's circulation and metabolisms to scientific knowledge suggests that science cannot arbitrarily exploit nature for seemingly endless progress (Burkett & Foster, 2005; Saitō, 2017; Swyngedouw, 2006). While attempting to know phenomena and processes of the Earth, science may (through its very knowledge-production practices) at the same time contribute to undermining the essential conditions for scientific knowledge. When applied to the understanding of scientific knowledge, a planetary spherical ontology indicates that there is no linear link between planetary conditions for scientific knowledge and scientific knowledge 'itself.' Both are circularly – or spherically – integrated, and they are as much each other's conditions as they are each other's outcome. While the notion of planetary scientific knowledge points to science as consisting of extended relations including both scholarly action in academia as well as mineral extraction, energy production and their related habitats and agents, the 'one' of the planetary emphasises that these relations do not progress endlessly towards infinite horizons. Scientific knowledge and the planet mutually shape each other's conditions and are each other's consequences (cf. Crawford, 2021; Crawford & Joler, 2018; Pasquinelli, 2017) in a spherical space.

The planetary term we developed above furthermore includes interdependency. Planetary scientific knowledge is bound neither to individual human nor non-human agents. The diverse actors that are connected in the extended relations

of scientific knowledge – from scientists, scientific apparatus and organisations to the energy and minerals they use, the mining and fabrication on which they depend and all the processes and practices involved in this – are all entangled with scientific knowledge. We also discussed Viveiros de Castro's (2004) account of Amerindian universality as another version of the aspect of the planetary that we called 'one shared world.' It is worthwhile re-thinking the technoscientific understanding of universality. In planetary terms the universal is not understandings emerging from scientific knowledge; it is the interconnected beings, materials, energies, practices etc., which planetary scientific knowledge both includes and from which it originates as their transformation. Thinking of scientific knowledge as planetary thus means that planetary scientific knowledge is never genuinely new but emerges as ontological reconfigurations of existing interdependent relationships.

An important point of applying the notion of planetary to scientific knowledge, and thus the understanding of scientific knowledge as 'one,' is that its interdependence and interconnection of components imply the multiplicity of scientific knowledge. Planetary scientific knowledge is experienced and unfolds differently in different places, similarly to what Danowski and Viveiros de Castro (2017) write about climate change. Although the product a cleanroom worker helping to etch chips in a semiconductor factory ends up in an HPC cluster at a research centre, it is likely that the worker does not consider their work to be a part of planetary scientific knowledge. The same, of course, is the case for most other human and non-human actors interwoven with the extended relations of planetary scientific knowledge. Pointing to the 'sharing' of planetary scientific knowledge emphasises that the semiconductor worker – along with other human and non-human actors of the extended relations of a certain planetary scientific knowledge – has a share in this knowledge, even if their share receives little or no acknowledgement. Each component of planetary scientific knowledge is situated somewhere, somehow in particular. Each component is akin to the others. Like all other components of the planetary scientific knowledge, a semiconductor worker is involved – probably more intensely involved – in other practices, and other extended relations, which intersect with planetary scientific knowledge and may intervene in its configuration.

Western cosmology's discontinuation of nature and culture underlined by Danowski and Viveiros de Castro (2017) has strong implications for the concept of scientific knowledge. Paraphrasing these authors, knowledge in this cosmology is scientific knowledge-without-us, people-less knowledge. This concept of scientific knowledge as outside the world – and the inside/outside distinction it implies – opens the path wide to extracting living beings and other planetary matter for scientific knowledge. Research shows how the very invention of modern science was achieved through a violent utilisation of nature (Freudenthal & McLaughlin, 2009). The spectrum under discussion is broad and finds various occurrences in modern technoscience, for example in biotechnological interventions that aim to reduce CO_2 emissions, yet primarily advance the capitalist frontier (Folkers & Opitz, 2022). As Burkett and Foster (2006: 137) phrase it while weaving in a quote by Marx: "[c]apitalist industrialisation is a process in which 'science presses natural agencies into the service of labour' (Marx, 1969[1865]: 34) under the pressures of private profit-making and competition." Likewise, decolonial scholars highlight how colonialism shapes modern science by assuming access to land, flattening (Indigenous) relations, and collecting things without attending to situated histories and taking seriously obligations to life in place (Liboiron, 2021; Schiebinger, 2004). Thinking instead in terms of planetary scientific knowledge includes (human and non-human) beings; it includes 'us,' i.e., those sharing the scientific knowledge from within, be it destructive or violent and constructive or collaborative alike.

The final point we discussed in relation to the concept of the planetary above drew attention to sharing in terms of the consequences of being in and of planetary relations. Transferred to scientific knowledge, it means that any of the components and agents of the extended relations of planetary scientific knowledge only engages parts of this knowledge. Moreover, with reference to Viveiros de Castro (2004) we may add that the extended

relations of planetary scientific knowledge are neither comprehensible nor controllable from any location of the extended relations. 'Broken-world thinking' (Jackson, 2014, 2023) and concepts of 'life in ruins' (e.g. Stengers, 2015; Tsing et al., 2017; Ureta, 2021) offer alternative conceptualisations to those of control and comprehension. Different from ideas of science as a matter of heading for new frontiers and scientific progress, these lines of thought suggest conceptualising planetary scientific knowledge not as production, but as ongoing processes of transformation, maintenance and repair.

The extended relations that make up planetary scientific knowledge do not extend endlessly, as discussed above. This is not only because they exist in a spherical space and return to their origins. We emphasise that it is also due to the constraints of the diverse social, material and planetary components making up scientific knowledge. Rather than emphasising the quantitative scarcity and limits of these components, we suggest – based on the reading of the mentioned authors and particularly of Haraway's (2016) work – to think in terms of living with the consequences of planetary scientific knowledge. This is about responding to the extended relations in which planetary scientific knowledge is entangled. Not all actors in the extended relations of planetary scientific knowledge have the same capacity to do so, just as not all profit similarly from the existence and maintenance of planetary scientific knowledge. An important question to address with the notion of planetary scientific knowledge is thus how its actors, communities and controversies shape – and have capacities to shape – spaces and occasions that make it possible to respond to the extended relations of planetary scientific knowledge in which they are entangled. This question also points to the reconfiguration of accountabilities and epistemic justice.

Before concluding our discussion, we would like to draw attention to limitations – or caveats – related to the current state of the notion of planetary scientific knowledge. Thinking in terms of extended relations may inspire a restless methodological drive to move on to the next component of a relation, rather than paying prolonged attention to fewer connections. A way to avoid shallow observations while attending to extended relations may be to engage in team-ethnographic approaches; sharing and distributing scientific agency. The understanding of extended relations may furthermore draw attention to certain empirical objects, and away from others. Energy-intensive, computationally demanding high-tech scientific knowledge and semiconductor extraction for scientific knowledge could be considered more relevant to engage with as planetary scientific knowledge, while neglecting scientific knowledges that sit at the margins of global supply chains of former European colonies, including Indigenous and decolonial knowledges. This is not our intention. The concept of planetary scientific knowledge should urge studies that attend both to the problems of mining-dependent and energy-intensive scientific knowledges as well as to less excessive epistemologies, which may unfold outside Euro-American academia.

Related to this, we have emphasised that not all actors have equal capacity to respond to or shape planetary scientific knowledge. The current state of the concept does not specify where leverage points are, nor how asymmetrical power relations within the extended relations can be contested or redirected. Current critical discussions around AI platforms outside academia, including communities refusing that chatbots are inevitable and pointing to their impact on workers' lives, energy consumption, and polluted rivers and landscapes elsewhere, are examples of increasing pressure against exploitation and extraction. Planetary scientific knowledge's comparable extended relations are rarely discussed in this context. It remains to be specified where potentials for transformation or resistance lie.

The notion of planetary scientific knowledge invokes multiple temporalities – geological pasts, capitalist histories, accelerations and slowing down – yet a deep historicising of these temporalities remains to be worked out. This applies for instance to the connection between colonial information orders and modern computational infrastructure. The concept of planetary scientific knowledge will benefit from more sustained engagement with specific historical trajectories,

emphasising these as more than mere backdrops for contemporary planetary scientific knowledge.

Finally, we have in this article focussed on conceptual development of the notion of planetary scientific knowledge, and although we hope the concept will guide empirical research, we have not unfolded a methodological procedure. We have included a few illustrative examples pointing to materials, energies, mining practices, supply chains, labour conditions, and deep inequalities, yet the practical challenge of tracing these and other empirical phenomena needs to be specified through empirical cases. Research designs based on the notion of planetary scientific knowledge could be ethnographic, discursive, reconstructive, practice analytical, or follow other methodological principles that are particularly well-equipped to combine a multitude of ontologies, sensitive to tensions, ambiguities and partialities, as well as those able to formulate non-reductive accounts. The conceptual framework of planetary scientific knowledge and concrete methodological applications are still to be bridged, and we encourage explorations and tests of the term's empirical relevance and scope.

Conclusion

The shift from thinking of scientific knowledge as socio-material to attending to it as planetary is both a continuation of a strong tradition of conceptualising scientific knowledge in STS, as well as a suggestion of a new conception of scientific knowledge as a component of the planet. With the notion of planetary scientific knowledge, we propose a shift from social studies of scientific knowledge to planetary studies of scientific knowledge (PSSK). Ideas of scientific knowledge as entangled in extended relations – or networks, arrangements or assemblages – are nothing new to STS. However, planetary relations are not explicitly theorised in STS as part of scientific knowledge. Planetary studies of scientific knowledge evoke a different imaginary from the plethora of studies attending to social-material scientific knowledge and its production in and beyond the boundaries of scientific institutions. These emphasise the study of apparatuses, inscription devices, data practices, scientific talk, standards and categories, regulations and politics, scientific cultures and much more. In addition to that, planetary studies of scientific knowledge draw attention to minerals and metals, rare earths, energy and their extractive production processes as also intimately involved in scientific knowledge, although often out of sight to those immediately involved with scientific knowledge. Importantly, more than adding such phenomena into the theorising of planetary scientific knowledge, PSSK imply a conceptualisation of scientific knowledge as extended relations in and through one shared world, as we have outlined above. The boundaries for answering questions of who is granted the right to speak in the name of science are considerably extended when planetary resource entanglements are also acknowledged as being involved in scientific knowledge. Conceptualising planetary relations as constituting and folded into scientific knowledge, PSSK thus urge new constitutions of research sites and new constellations of actors (and alterities, in Spivak's (1999) sense) in studies of scientific knowledge in order to unravel and critically discuss how scientific knowledge through its very ontology contributes to shaping and transforming planetary relations. The notion of planetary scientific knowledge moreover helps draw attention to not only scientific knowledge as planetary, but also to the wealth of literature that attends to this relation.

The move from social studies of scientific knowledge to planetary studies of scientific knowledge is more than a question of scientific insights and academic debate. This article's conceptual development was motivated by concern over science's lack of engagement with its role in shaping the planet. The German National Academy of Sciences Leopoldina published a statement in 2025 critiquing the bureaucratisation of the sciences and its detrimental effects on scientific freedom (Krieg et al., 2025). In its final chapter, the report differentiates between the core tasks and secondary purposes of science and research. Secondary purposes include diversity, justice and environmental issues and, according to the report, such 'science accessorial' (*wissenschaftsakzessorisch*) (Krieg et al., 2025: 18) purposes come at the expense of science's core tasks. The tradition of STS has, as

discussed above, thoroughly documented that gender, culture, and geopolitics are not merely decorative additions to science, but constitutional and inherent dimensions of scientific knowledge. Planetary studies of scientific knowledge in a similar vein draw attention to how planetary processes are indeed ontologically foundational to scientific knowledge and that scholars need to become equipped to attend to the concrete ways in which scientific knowledge has planetary consequences. The Leopoldina report is just one among many contemporary contestations against science and research's attention to planetary relations. PSSK mark a deeply reflexive attempt to draw attention to the planetary consequences of scientific knowledge, which – similar to debates on the freedom of science – encourages reconsideration of science not only as epistemic, social and technical, but as addressing planetary processes that include universities' procurement activities, energy management and science politics, as well as computing, laboratory and building infrastructure, etc., and how thus certain relations are woven and others are cut, with different consequences for the entities entangled based on how the relations are made. This sensitivity points to ourselves, to scholars and scientific institutions, and our interaction with a world that is not only social and, technical, but also and planetary. This ultimately encourages interventions into how actors of scientific knowledge and our institutions respond and adapt to our planetary relations, and can be equipped and create occasions to rework our practices and infrastructures to engage in new and responsible ways with the extended planetary relations of the one shared world we inhabit.

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Notes

1 See e.g. Berné et al. (2022) and Lannelongue and Inouye (2023). Quantifying scientific energy and mineral consumption has particularly been done in relation to computing. This is however complicated and hardly possible to do with precision. Nonetheless, it is not contested that there has been an increased use of computing throughout the younger history of science (Agar, 2006) and of high-performance-computing particularly after the recent simplified access to artificial intelligence applications (e.g. Dongarra and Keyes, 2024). With these developments, more energy, materials and minerals for computer and server parts also become entangled with scientific knowledge practices.

2 The Independent Galilean Pulsar is a highly magnetised rotating neutron star discovered in 1969 at the Steward Observatory, USA.

3 Social Construction of (Science and) Technology (SCOT) emphasised the importance of human interpretation and re-interpretation in the construction of knowledge, just as Collins and Yearley (1992) insisted on the moral primacy of humans and the need to frame knowledge and the social in terms of (human) meaning and intersubjectivity. Actor-Network Theory (ANT), on the other hand, followed the lead of ethnomethodological science studies combined with Greimas' semiotics to point to knowledge as always interweaving both human and non-human actors, and social and material dimensions, resulting in a material-semiotic understanding of science, as Law (2008) characterises this ontology.

4 The 'blue marble' imaginary views the planet from a distance and has, among other things, motivated extractivist space explorations such as Jeff Bezos' recent Blue Origin project (Chaudhary, 2024).

5 The cited authors along with Malm and Hornborg (2014) and many others point to the 'Anthropocene' as an ambiguous figure. It is consummately anthropocentric to name a whole geological epoch after the human, just as the Anthropocene suggests a universalising scope evoking an all-encompassing, authoritative view. However, the term has also proven to inspire arts, activism and critical research, just as it resonates with situated everyday life experiences of discourses and practices of climate change. The survival of the term in these domains after its rejection in 2024 by the International Commission on Stratigraphy only confirms its potential for describing, analysing and navigating contemporary complex planetary lives, not despite, but because of, its ambiguity.

6 See Verran (2001) for further discussions on part-whole ontology.