Spacetime realism against super-substantivalism

In my talk I will focus on interpretative and speculative issues concerning the relation between spacetime and matter in standard general relativity (GR) in the context of the debates on the reality of gravitational energy and conservation laws in GR. I look at those issues through the lens of scientific realism. My main claim is that being a realist with respect to GR – a *spacetime realist* – works better with dualistic ontology of spacetime and matter than monism about spacetime.

More recent discussions on scientific realism(s) undermine or downplay metaphysical components of this family of positions (Chakravartty, van Fraassen 2018, Corti 2023). Scientific realism may be characterized as consisting of three thesis: semantic (scientific discourse about unobservable entities should be taken literally), epistemic (science's content is approximately true), metaphysical (the world has a definite and mind-independent structure) (Psillos 1999, Rowbottom 2019). Anjan Chakravartty comments on the metaphysical thesis that "a *scientific* realist [is not committed] to any particular beliefs regarding what are, arguably (at best), implicit subject matters of scientific investigation, such as the nature of properties or laws of nature" (Chakravartty, van Fraassen 2018: 24). I disagree with the claim that the metaphysical thesis, as presented above, regarding the particular, successful and mature, scientific theories needs to be that minimalistic. Being a realist in the context of GR means being a *spacetime realist*, i.e. viewing spacetime as a real existent, a "mind-independent structure". But there is definitely more to the story. Discussions about the *nature of spacetime* and its relations with matter present considerable depth and complexity, facilitate understanding or even have the potential to be heuristic tools in motivating scientific programmes (Lehmkuhl 2018, Duer, Calosi 2021).

To be a spacetime realist usually means to adopt some variation of substantivalism which, roughly, means that spacetime is considered as a substance which exists over and above matter (material fields); spacetime relations are internal to that substance and not merely the configurations between bodies/events/material fields. Being a substantivalist means accepting a two-category ontology: of spacetime and matter. While the literature on versions of substantivalism (and on their rivals – relationalism) is vast (dealing also with other important issues, e.g. determinism or spacetime symmetries), some topics were less explored philosophically during the decades. One of those topics received detailed treatment recently – the existence of gravitational energy and the status of conservation laws in GR (Hoefer 2000, Lam 2011, Lehmkuhl 2018, Curiel 2019, Read 2020, Duer 2021, Pitts 2023). This topic has certain bearings on spacetime-matter dualism, and, as I see it and will explain it shortly, at least partly on general realistic stance with respect to spacetime.

An important argument for interpreting spacetime as a substance comes from (Earman, Norton 1987): [in GR] "The metric tensor now incorporates the gravitational field and thus, like other physical fields, carries energy and momentum . . . in a way that forces its classification as part of the contents of spacetime." If one chooses, and there are reasons to do so, the metric tensor as the representor of spacetime, than spacetime may be treated as possessing (gravitational) energy, making it as real as material fields (Hoefer 2000). This upholds the spacetime (gravity) – matter dualism. This argument however was subjected to some vigorous critiques (Hoefer 2000, Curiel 2019, Duer 2021, Pitts 2023) based on strong arguments (concerning the pseudotensorial character of representation of putative gravitational energy, concerning the general lack of well-posed conservation laws in GR, concerning the necessity of spacetimes with background structure to defend the validity of conservation of gravitational stress-energy) that yield different outcomes: some separate spacetime realism from gravitational energy realism (Duer 2020), some defend gravitational energy realism understood as spacetime energy (Read 2020) while others accept the existence of gravitational energy, deny its identification with spacetime energy, and propose certain background structures (Pitts 2023).

One of the metaphysical upshots from these considerations is that (i) the stress-energy tensor in GR represents jointly *non-fundamental properties* of the world (since this tensor is definable only with reference to a given spacetime metric) and as such may be thought of as ontologically dependent on the metric, including its potential reducibility to the metric; (ii) spacetime, as such, may not carry any energy, so spacetime realism requires arguments independent from the question of gravitational energy and conservation laws in GR. (i) may imply that spacetime-matter dualism is false, while (ii)

may invite non-standard analysis in arguing for, e.g., explanatory value of spacetime (Duer 2019). Putting aside relationalism, an interpretative option that recently have been explored in the context of (i) and (ii) is the so-called *super-substantivalism* (a view that comes at least in three forms: a) the identity view, equating matter with spacetime region(s), b) the constitution view, in which matter is considered as being built out of parts of spacetime, and the priority view, in which spacetime is considered ontologically prior/fundamental with respect to matter).

In my talk, after presenting some details about the issues mentioned above, I will argue that dualism generally should be preferred over super-substantival monism. I will mainly argue on the basis of the lack of independent theory of matter in relativistic physics and on the basis of the global character of those spacetimes which may be considered as describing the universe as a whole My goal will be to show that within spacetime-matter dualism we can interpret spacetime in a holistic way and treat it as (part of) the largest physical system - the universe - which cannot be treated as an open system exchanging energy with a different system, since there is no outside system with which the actual universe as a whole can interact. This will provide an *metaphysical* explanation as of why conservation laws in GR are ill-posed. For the time being I won't put forward any interpretative claims on gravitational energy. I only assume that spacetime realism neither implies the reality of gravitational energy nor can be defended by this concept.

Dualistic ontology with holistically understood spacetime in the context of GR seem to suit the realist better, as I claim. Realists tend to focus on (best) explanations, and here, while accepting that gravitational energy and conservation laws are troublesome, the realist can provide deeper explanation of why this fact obtains. This fares well in comparison with super-substantivalism on the grounds of, e.g., parsimony – we are not committed to (perhaps needlessly?) revisionary scientific programmes in physics nor extra metaphysical assumptions about the ontological dependence relation. This is especially ironic because monism, *prima facie*, looks like a more economical interpretative option.

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