Philosophy of the geometric trinity: a digest

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The 'geometric trinity' of gravitational theories has three nodes: (a) general relativity (GR), in which gravitational effects are manifestations of spacetime curvature, (b) the teleparallel equivalent of GR (TEGR), in which gravitational effects are manifestations of spacetime torsion, and (c) the symmetric teleparallel equivalent of GR (STEGR), in which gravitational effects are manifestations of spacetime non-metricity. (For a recent review from the physics literature, see Jiménez et al. (2019).) These theories are empirically equivalent to each other (in the sense that their actions differ by a boundary term) and hence *prima facie* present a case of underdetermination of theory by evidence.

Here, I'll try to review, as quickly as possible, all the existing philosophical literature on the geometric trinity. (My aim is to be exhaustive, so if you spot something missing, please let me know!)

1 Philosophy of TEGR

Philosophers have discussed TEGR since Lyre and Eynck (2003) and Knox (2011, 2013). In recent years, there has been quite a significant upturn in the number of philosophy articles on TEGR, which have covered the following topics:

1. *Underdetermination:* Knox (2011) argues that there is no genuine underdetermination between GR and TEGR because the latter is a mere reformulation of the former. This claim is resisted by Mulder and Read (2024) (who engage directly with Knox) and Wolf et al. (2024b) (who consider the issue in the context of tests of GR).
   (a) Dürr and Read (2024) and Roberts (2025) consider whether this underdetermination could be overcome by appealing to geometric conventionalism.
   (b) March et al. (2024a), Weatherall and Meskhidze (2024), and Wolf et al. (2024b) all argue that the 'common core' of the geometric trinity is GR, so Occamist reasons militate in favour of preferring this theory. (So, these authors agree with Knox that GR is to be preferred over TEGR, albeit not for her reasons.)

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(c) Wolf and Read (2023) consider the equivalence of GR and TEGR in the context of the question of whether the theories have the same representational capacities (especially in the context of boundary conditions).

(d) Fankhauser and Read (2024) discuss upshots of underdetermination in the geometric trinity in the specific context of explanations of gravitational redshift.

2. *Theoretical equivalence:* Is TEGR *really* equivalent to GR? This question was taken up by Weatherall and Meskhidze (2024) who issued a negative answer (because in a technical sense TEGR has more 'structure' than GR); the analysis was then developed further by March et al. (2025), who considered various different versions of TEGR in the literature (including those using Cartan geometries and higher gauge theory) and whether or not they are equivalent.

3. *Non-relativistic limits:* Read and Teh (2018) and Schwartz (2023) argue that the non-relativistic limit of the GR–TEGR correspondence is the correspondence between Newton–Cartan theory and potential-based Newtonian gravity (formalised in Trautman geometrisation/recovery). Meskhidze and Weatherall (2024) present a different torsionful non-relativistic theory and claim it is the 'teleparallel equivalent' of Newton–Cartan theory; this claim is engaged with by March et al. (2024b).

4. *Equivalence principles:* Read and Teh (2023) consider the 'equivalence principle' in its various forms in the context of both TEGR and non-relativistic theories.

5. *Background structure:* Read (2023) asks whether TEGR is 'background independent' in the sense of have any 'fixed' background structure in its models.

6. *Status as a gauge theory:* From various angles, Dürr and Read (2025), March et al. (2025), Wallace (2015), and Weatherall (2025) all assess whether it is correct to understand TEGR as a 'gauge theory' (of translations), as is sometimes claimed in the literature (see e.g. Aldrovandi and Pereira (2013)).

2 Philosophy of the geometric trinity

The above philosophical work has specifically to do with TEGR; only more recently have philosophers started to discuss the entire geometric trinity of gravity. In particular, the following work has been accomplished:

1. *Underdetermination:* Wolf et al. (2024b) consider underdetermination in the context of the entire geometric trinity of gravity.

2. *Coincident general relativity:* A particular version of STEGR is called 'coincident general relativity' (CGR). Various conceptual aspects of this are assessed by Read and Wolf (2025).

3. *Theoretical equivalence:* Weatherall (2025) shows that, like TEGR, STEGR is not equivalent to GR, because it has more 'structure'. Read and Wolf (2025) build on this by showing that CGR has more 'structure' than STEGR.

4. *Non-relativistic limits:* Wolf et al. (2024a) discuss the non-relativistic limit of the entire geometric trinity, to construct a 'non-relativistic geometric trinity'. March et al. (2024a) identify the 'common core' of this non-relativistic trinity.

3 Future prospects

Although (arguably) much of the conceptual structure of the geometric trinity has been explored (and with any luck clarified) in the above work, there remain a few threads worthy of further exploration:

1. *Gravitational energy:* It is sometimes claimed (see e.g. Aldrovandi and Pereira (2013)) that gravitational energy is less problematic in (S)TEGR than in GR, because it is tensorial. Are these claims correct?

2. *Connections with metric-affine gauge theory:* How do (S)TEGR (particularly when understood in terms of e.g. Cartan geometries) fit into the framework of metric-affine gauge theory pioneered by Hehl et al. (1995)?

3. *Underdetermination reprise:* Recently, some physicists (e.g., Iosifidis and Hehl (2024) and Zhou (2024)) have raised novel arguments to the effect that there is no genuine underdetermination in the case of the geometric trinity of gravity; these deserve to be assessed.

4. *Gomesification:* Do (S)TEGR, understood as gauge theories (in whatever form), admit of the kinds of geometrical reformulations (from principal fibre bundles to vector bundles) recently undertaken by Gomes (2024)?

5. *Ultra-relativistic gravity:* The ultra-relativistic ($c \to 0$) limit of GR has only recently been explored by philosophers (see March and Read (2025)). Mirroring Wolf et al. (2024a), would it be possible to construct an ultra-relatistic geometric trinity of gravitational theories, and what interesting conceptual features would that trinity manifest?

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