

Gödel, Kant, and the Incompleteness of Physical Knowledge

Brigitte Falkenburg

1. Introduction
2. Gödel and Kant
3. Limits of Physical Knowledge
4. Back to Gödel

Gödel, Kant, and the Incompleteness of Physical Knowledge

1. Introduction

1. Introduction

Gödel's Theorems $\leftarrow ? \rightarrow$ Limits of Physical Knowledge

- Gödel's Theorems \rightarrow Limits of Provability & Mathematical Knowledge
- Relevant for Limits of Physical Knowledge?
- Measurement in Quantum Mechanics $\leftarrow ? \rightarrow$ Gödel-type Undecidability

A. Perales-Eceiza, T. Cubitt, et al. 2025: *Undecidability in Physics: A Review*

“...it seems that Gödel himself did not want to explore this path.¹⁶”

¹⁶ John Wheeler asked Gödel about the connection between his incompleteness and Heisenberg's Uncertainty Principle and “Gödel got angry and threw me out of his office”

Barrow (2011): *Gödel on Physics*

“Gödel was not so minded as to draw any strong conclusions for physics from his incompleteness theorems. He made no connections with the uncertainty principle of quantum mechanics. [...] In fact, Gödel was rather hostile to any consideration of quantum mechanics at all.”

1. Introduction

Gödel's Theorems $\leftarrow ? \rightarrow$ Limits of Physical Knowledge

- Gödel's Theorems \rightarrow Relevant for Limits of Physical Knowledge?
- Discussion on Quantum Measurements since the 1970s:

M. Zwick (1978): *Quantum Measurement and Gödel's Proof*

“The measurement problem in quantum mechanics has the character of a fundamental incompleteness within that theory similar to the [Gödel] incompleteness [...]. The difficulty of describing the measurement process [...] may reflect the limitations of formal language, and quantum theory may thus require a formalism consisting of two levels of description, [...] whose relationship resembles that of a calculus and meta-calculus.”

- Quantum Theory of Measurement:

P. Mittelstaedt (1998): *Interpretation of QM & Measurement Process*

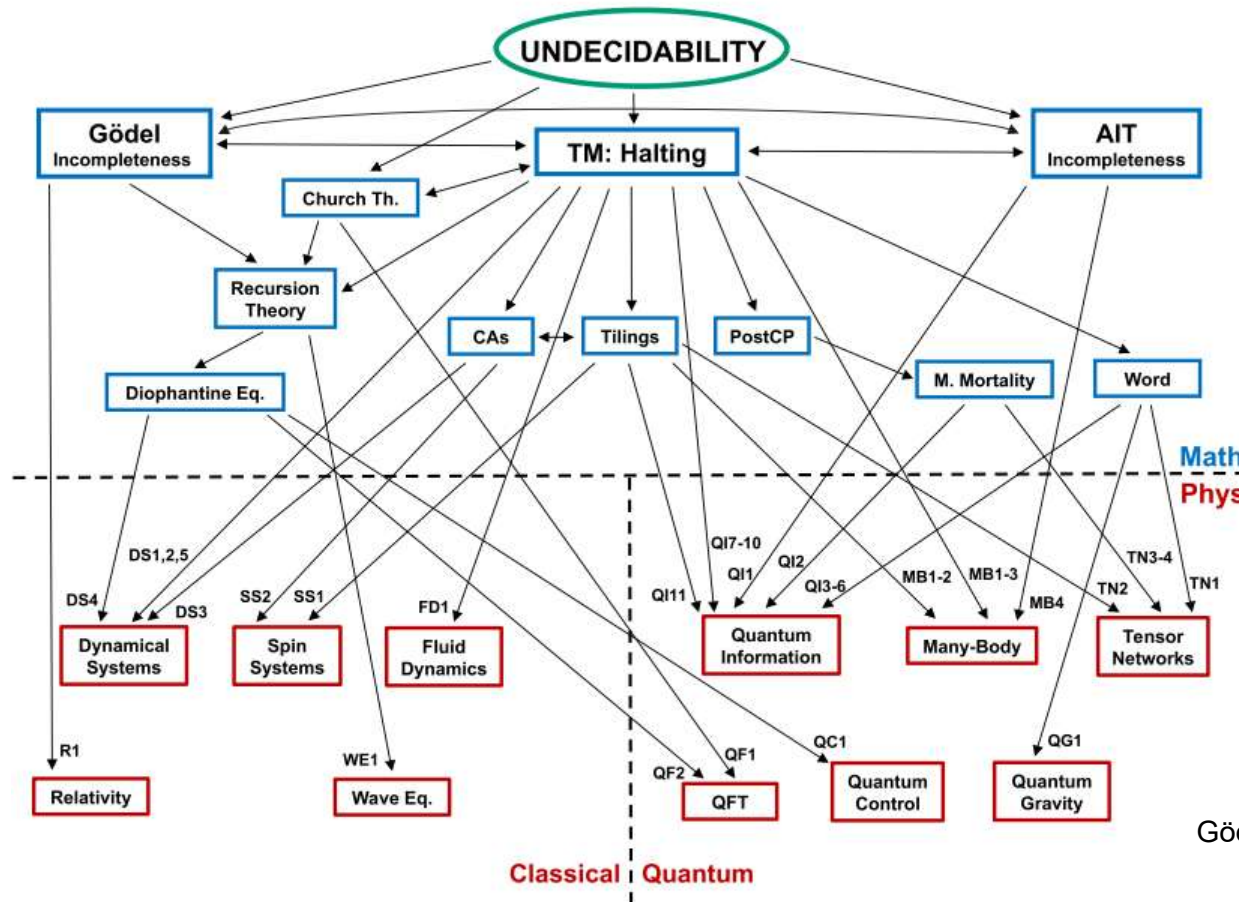
- PROOF: Quantum mechanics *only* semantically complete at the probabilistic level
- The semantic incompleteness of QM is *analogous* to Gödel's incompleteness
- BUT how far does the analogy go? UNCLEAR!

1. Introduction

Gödel's Theorems $\leftarrow ? \rightarrow$ Limits of Physical Knowledge

- Recent Results on Undecidability in Physics:

A. Perales-Eceiza, T. Cubitt, et al. 2025: *Undecidability in Physics: A Review*



- Many Formal Results
- No Recent Results on Quantum Theory of Measurement
- Philosophical Consequences of Undecidability in Physics?
- Ontology & Metaphysics?
- Gödel's Leibnizian Ontology $\leftarrow ? \rightarrow$ Kant's *Critique of Transcendental Realism*

Gödel, Kant, and the Incompleteness of Physical Knowledge

2. Gödel and Kant

2. Gödel and Kant

Kant's Influence on Gödel?

- Remarks on Kant in Gödel's Philosophical Notebooks?

Relatively few remarks on Kant's epistemology & metaphysics;
NO remarks on Kant's critique of traditional (rationalist) metaphysics

- Today, mainly: Discussion on Ideality of Time in Kant & Gödel
- *Methodological* Analogies between Kant & Gödel?

S. Kovač (2008): *Gödel, Kant, and the Path of a Science*

“Comparison with Kant can thus be very helpful for an understanding and reconstruction of Gödel's philosophy, and of his aim to give a secure foundation to philosophy and science.”

Although Gödel is *much closer* to Plato & Leibniz than to Kant,

- “we can note an interesting **parallel** between Gödel's considerations on the philosophy of **mathematics** and Kant's considerations on **metaphysics**”.
- i.e., the **search for certainty** = for “the secure path of a science” (Kant 1787).

2. Gödel and Kant

Kant's Influence on Gödel?

- Parallel between Kant & Gödel, on the “secure path of a science”?

S. Kovač (2008): *Gödel, Kant, and the Path of a Science*

“For Gödel, the incompleteness theorem was the exact proof of the incorrectness of the Hilbertian variant of Kantianism” (i.e., Hilbert’s finitism).

Gödel rejects Kant’s dualism of sensibility / understanding,
appearances / things in themselves, **BUT**

- “a kind of ‘Copernican turn’ has to secure the path of a science for mathematics”, which is a *variant of Kant’s Copernican turn* in metaphysics:
- “There is really a sort of ‘Copernican turn’ in Gödel’s attempt to rescue the “right” direction in mathematics – but without Kant’s ‘boundless subjectivism’ and the ‘unknowability of the things in themselves’.”
- **Main difference:** Gödel believes in an objective, mind-independent perception of objects, i.e., in an *intellectual intuition of concepts*.

2. Gödel and Kant

Kant's Influence on Gödel?

- HOWEVER, Kovač *misconstrues* the difference to a certain extent:

S. Kovač (2008): *Gödel, Kant, and the Path of a Science*

“With respect to the success of the ‘Copernican turn’ in general, Kant claims that this **experiment (to try the option that experience should conform to concepts)** ‘succeeds as well as could be desired’ (B XVIII), and that it is in fact carried out in his Critique of Pure Reason. Gödel [...], in contrast, as already noted, does not expect such quick results. He expects the full establishment of mathematics (and metaphysics) only from the future development of phenomenological methods [...]”.

BUT Kant’s “experiment of pure reason” refers to the **cosmological antinomy**:

“As for objects insofar as they are **thought merely through reason** [...] but that [...] cannot be given in experience at all – the **attempt to think them** [...] will provide a **splendid touchstone** of what we assume as the **altered method of our way of thinking**, namely that we can cognize of things *a priori* only what we ourselves have put into them.” (B xviii)

2. Gödel and Kant

Kant's Influence on Gödel?

➤ Kant's Copernican turn:

The “experiment of pure reason” (1787) refers to the **cosmological antinomy**:

“As for objects insofar as they are **thought merely through reason** [...] but that [...] cannot be given in experience at all – the **attempt to think them** [...] will provide a **splendid touchstone** of what we assume as the **altered method of our way of thinking**”.

“Now if we find that on the assumption that our cognition from experience conforms to the **objects as things in themselves**, the unconditioned cannot be thought at all without **contradiction**, but that on the contrary, if we assume that our representation of things as they are given to us does not conform to these things as they are in themselves but rather that these **objects as appearances** conform to our way of representing, then the **contradiction disappears** [...]” (B xxi)

- Transcendental realism → cosmological antinomy
- Transcendental idealism → antinomy disappears

2. Gödel and Kant

Kant's Influence on Gödel?


- Gödel's Copernican turn → metaphysical realism of concepts
Anti-Kantian turn: Mathematical realism / Platonism & Leibnizian ontology
- Kant's Copernican turn → transcendental idealism & dualism
Experiment of reason → transcendental realism is self-contradictory
- How convincing is Kant's argument?
→ Depends on his proofs for the cosmological antinomy!
- Gödel does NOT refer to Kant's cosmological antinomy
→ He *neglects* Kant's claim that cosmological knowledge cannot be completed
- Was Kant right, or is the antinomy bound to 18th century science?
→ Is there any tenable relation to undecidability in physics?

Gödel, Kant, and the Incompleteness of Physical Knowledge

3. Limits of Physical Knowledge

3. Limits of Physical Knowledge

Structure of Kant's Cosmological Antinomy:

- 2 x 2 pairs of incompatible claims about WORLD as absolute totality
- “Mathematical” antinomy \leftrightarrow spatio-temporal structure of the world:
 1. World = finite \leftrightarrow infinite in space & time
 2. Substances consist \leftrightarrow do not consist of simple parts (atoms, monads)
- Kant: The proofs are plausible, but fallacious. Source of fallacy:
 - WORLD in SPACE & TIME = SUM TOTAL of PHENOMENA
 - The WORLD as an absolute totality = unrelated thing-in-itself (noumenon)
 - Everything WITHIN the world = relational appearance (phenomenon)
 - The WORLD = noumenon = totality of phenomena
 - Confusion: PHENOMENAL WORLD  NOUMENON

3. Limits of Physical Knowledge

Structure of Kant's Cosmological Antinomy:

- “Mathematical” antinomy \leftrightarrow spatio-temporal structure of the world:
 1. World = finite $\leftarrow!?\rightarrow$ infinite in space & time
 2. Substances consist $\leftarrow!?\rightarrow$ do not consist of simple parts (atoms, monads)
- Kant: The proofs are plausible, but fallacious. Source of fallacy:
 - WORLD in SPACE & TIME = SUM TOTAL of PHENOMENA

“Of two mutually contradictory propositions both cannot be false save when the concept underlying them both is itself contradictory; e.g., the two propositions: a **square circle** is round, and: a square circle is not round, are both false. [...] Now **underlying the first two antinomies**, which I call **mathematical** because they concern adding together or dividing up the homogeneous, is a **contradictory concept of this type**; and by this means I explain how it comes about that thesis and antithesis are false in both.” (*Prolegomena*, § 52b)

3. Limits of Physical Knowledge

Structure of Kant's Cosmological Antinomy:

- “Mathematical” antinomy \leftrightarrow spatio-temporal structure of the world:
 1. World = finite $\leftarrow!?\rightarrow$ infinite in space & time
 2. Substances consist $\leftarrow!?\rightarrow$ do not consist of simple parts (atoms, monads)
- Kant: The proofs are plausible, but fallacious. Source of fallacy:
 - WORLD in SPACE & TIME = SUM TOTAL of PHENOMENA

“Now if I ask about the **magnitude of the world with respect to space and time**, for all of my concepts it is just as impossible to assert that it is infinite as that it is finite. For neither of these can be contained in experience, because it is not possible to have experience either of an infinite space or infinitely flowing time, or of a bounding of the world by an empty space or by an earlier, empty time; these are only ideas. Therefore the magnitude of the world, determined one way or the other, **must lie in itself, apart from all experience**. But this **contradicts the concept of a sensible world, which is merely a sum total of appearance, [...] not a thing in itself.**” (*Prolegomena*, § 52c)

3. Limits of Physical Knowledge

Structure of Kant's Cosmological Antinomy:

- “Mathematical” antinomy \leftrightarrow spatio-temporal structure of the world:
 1. World = finite $\leftarrow!?\rightarrow$ infinite in space & time
 2. Substances consist $\leftarrow!?\rightarrow$ do not consist of simple parts (atoms, monads)
- Kant: The proofs are plausible, but fallacious. Source of fallacy:
 - WORLD in SPACE & TIME = SUM TOTAL of PHENOMENA

“From this it follows that, since **the concept of a sensible world existing for itself is self-contradictory**, any solution to this problem as to its magnitude will always be false, whether the attempted solution be affirmative or negative. – The same holds for the **second antinomy** [...]. To assume that **an appearance, e.g., of a body, contains within itself, before all experience, all of the parts to which possible experience can ever attain, [...] contradicts itself** and hence also contradicts every solution to this misunderstood problem, whether that solution asserts that bodies in themselves consist of infinitely many parts or of a finite number of simple parts.” (*Prolegomena*, § 52c)

3. Limits of Physical Knowledge

Structure of Kant's Cosmological Antinomy:

- “Mathematical” antinomy \leftrightarrow spatio-temporal structure of the world:
 1. World = finite $\leftarrow!?\rightarrow$ infinite in space & time
 2. Substances consist $\leftarrow!?\rightarrow$ do not consist of simple parts (atoms, monads)
- Kant: The proofs are plausible, but fallacious. Source of fallacy:
 - WORLD in SPACE & TIME = SUM TOTAL of PHENOMENA
 - Kant has often been criticized (e.g. Russell 1903). BUT:
 - He knew that the proofs are unsound
 - His argument is **cosmological**, not mathematical
 - Kant's Conclusion: Our Physical Knowledge Cannot be Completed
 - **BUT: Is Kant's argument tenable?**

3. Limits of Physical Knowledge

Structure of Kant's Cosmological Antinomy:

- “Mathematical” antinomy \leftrightarrow spatio-temporal structure of the world:
 1. World = finite $\leftarrow!?\rightarrow$ infinite in space & time
 2. Substances consist $\leftarrow!?\rightarrow$ do not consist of simple parts (atoms, monads)
- Kant: The proofs are plausible, but fallacious. Source of fallacy:
 - WORLD in SPACE & TIME = SUM TOTAL of PHENOMENA
 - Is Kant's cosmological antinomy **obsolete**?
 - His proofs are based on 18th century science & metaphysics
 - Kant argues in terms of **experience** rather than **theory & experiment**
 - Kant's Conclusion: Our Physical Knowledge Cannot be Completed
 - **BUT: It has a Rationale!**

3. Limits of Physical Knowledge

Rationale of Kant's Cosmological Antinomy:

- Let us look at the relation theory \leftrightarrow experiment:
 - Theories \leftrightarrow empirically underdetermined
 - Experimental results \leftrightarrow instantiate theories
- Experimental Method \leftrightarrow Isolated Systems & Reproducible Results
- Cosmological Theory \leftrightarrow Model of the WORLD (Universe)
 - Perfect Model of the WORLD $\leftarrow! \rightarrow$ Sum Total of Experimental Results
 - Gravitation $\leftarrow! \rightarrow$ There are no isolated systems in the universe
 - Experimental results $\leftarrow! \rightarrow$ Only approximations of cosmological theory
 - No perfect test of any cosmological model possible!
 - Tension between Model of the WORLD and Testability
 - Relation to Kant's antinomy?

3. Limits of Physical Knowledge

Rationale of Kant's Cosmological Antinomy:

- Experimental Method ↔ Isolated Systems & Reproducible Results
 - ↔ law-like behaviour of identical cases
 - ↔ “laboratory view” of physics / nature
- Cosmological Theory ↔ Model of the WORLD (Universe)
 - ↔ theory of one object only
 - ↔ “cosmological view” of physics / nature
- Relation to Kant's antinomy? Analogue to Kant's 2nd antinomy:
 - “laboratory view” ↔ isolated systems (substances), as instances of laws
 - “cosmological view” ↔ the WORLD (Universe), as relational totality

(E. Scheibe 1991)

→ PROBLEM: Laboratory View  Cosmological View

→ For Cosmology, “Law of Nature” = Self-Contradictory Concept!

Gödel, Kant, and the Incompleteness of Physical Knowledge

4. Back to Gödel

4. Back to Gödel

This Analogy to Kant: Just Philosophical Quibbling?

- PROs: Many Well-Established Laws of Nature
 - Self-uniformity of nature at many scales
 - Including many quasi-classical approximations of quantum processes
 - Universal validity of quantum laws everywhere within nature
- CONs: Notorious conceptual problems of quantum gravity!?
 - Due to quantum measurement problem, physics is epistemically incomplete
 - No “theory of everything” (TOE) is in sight
 - Meaning of “quantum theory of the universe” *unclear*
- Undecidability in Gödel’s sense? Probably (Kiefer 2024), but there is no proof.
- But according to my above considerations, a TOE should be untestable.

4. Back to Gödel

Gödel's Notes on Quantum Mechanics

- Gödel's notes on QM (1935/36) $\leftarrow? \rightarrow$ Wheeler's anecdote (after 1938)

“John Wheeler asked Gödel about the connection between his incompleteness and Heisenberg's Uncertainty Principle and “Gödel got angry and threw me out of his office.”
(Perales-Eceiza et al. 2025, p.12, n.16)

“Gödel was not so minded as to draw any strong conclusions for physics from his incompleteness theorems. [...] In fact, Gödel was rather hostile to any consideration of quantum mechanics at all.”
(Barrow 2011, pp. 260-261)

- Einstein's influence on Gödel?

“Those who, like Gödel, worked at the Institute for Advanced Study (no one really worked with Gödel) believed that this was a result of his frequent discussions with Einstein, who, in the words of John Wheeler (who knew them both), ‘brainwashed Gödel’ into disbelieving quantum mechanics and the uncertainty principle.”

(Barrow 2022, p.261)

4. Back to Gödel

Gödel's Notes on Quantum Mechanics

- Gödel's notes on QM (1935/36):
 - Influence of Jordan's positivism
 - Close to Copenhagen interpretation (J. v. Neumann)
 - BUT objectivistic interpretation of measurement outcomes

- Parallelism between universal set & Kant's thing-in-itself:

“Parallelismus zwischen Allmenge und Ding-an-sich:
In keiner Annäherung an die Wirklichkeit kommt ein objektives Ding-an-sich vor.
[Nur in der widerspruchsvollen Theorie, welche die klassische Physik ist.]
Plancksche Antin. ... Russellsche Antin.” (in: Lethen & Passon 2021, p.69)

- Analogy between Russell's antinomy & “Planck's antinomy”:

<p><i>“Russells antin.</i> In keiner mathematischen Theorie kommt die Allmenge vor. (Nur in der widerspruchsvollen alten.)</p>	<p><i>Plancks antin.</i> In keiner Annäherung an die Wirklichkeit kommt ein vollkommen objektives Ding-an-sich vor. (Außer in der widerspruchsvollen klassischen.)” (<i>ibid.</i>, p.109)</p>
--	---

4. Back to Gödel

Gödel's Notes on Quantum Mechanics

- Gödel's notes on QM (1935/36):
 - Influence of Jordan's positivism
 - Close to Copenhagen interpretation (J. v. Neumann)
 - BUT objectivistic interpretation of measurement outcomes
- Parallelism between universal set & Kant's thing-in-itself:

“Parallelism between universal set and thing-in-itself:
No approximation of reality includes an objective thing-in-itself.
[Only the contradictory theory that is classical physics.]
Planck's antinomy ... Russell's antinomy.” (in: Lethen & Passon 2021, p.69)
- Analogy between Russell's antinomy & “Planck's antinomy”:

<i>“Russell's antinomy</i>	<i>Planck's antinomy</i>
No mathematical theory	No approximation of reality
includes the universal set. (Only the contradictory old one does.)	includes a completely objective thing-in-itself. (Only the contradictory classical does.)” (<i>ibid.</i> , p.109)

4. Back to Gödel

Gödel's Notes on Quantum Mechanics

➤ Analogy between Russell's antinomy & "Planck's antinomy":

"N.B.: Widerspruch bedeutet: Widerspruch im Fall der obigen Antinomie.
Hauptproblem der Physik: Welches ist die Struktur derjenigen transfiniten Folge von Theorien, welche die klassische Theorie einer „objektiven Welt“ zu ersetzen bzw. zu approximieren (?hat)? Ein wesentlicher Bestandteil dabei muss die monadolog. Struktur der Welt sein. Jede dieser Theorien ist eine Zwischenstufe zwischen Solips. und (widerspruchsvoller) objektiver Wirklichkeit und hat vielleicht die Struktur der Monadologie, d.h., es gibt keine objektive Wirklichkeit, sondern nur die verschiedenen Weltbilder der Monaden, zwischen denen gesetzmäßige Zusammenhänge bestehen.“

(in: Lethen & Passon 2021, p.109)

4. Back to Gödel

Gödel's Notes on Quantum Mechanics

- Analogy between Russell's antinomy & "Planck's antinomy":

"Postscript: Contradiction means: contradiction in the case of the above antinomy. The **main problem in physics**: What is the **structure of the transfinite sequence of theories that (?should) replace or approximate the classical theory of an 'objective world'**? An essential component of this must be the **monadological structure of the world**. Each of these theories is an intermediate stage between solipsism and (contradictory) objective reality and perhaps has the structure of monadology, i.e., **there is no objective reality, but only the different world views of the monads, between which there are lawful connections.**" (in: Lethen & Passon 2021, p.109)

- Move from Kant's epistemology to a Leibnizian ontology...
- ...and to a relational interpretation of Quantum Mechanics?!

4. Back to Gödel

Gödel's Notes on Quantum Mechanics

- Analogy between Russell's antinomy & "Planck's antinomy":

"Postscript: Contradiction means: contradiction in the case of the above antinomy. The main problem in physics: What is the structure of the transfinite sequence of theories that (?should) replace or approximate the classical theory of an 'objective world'? An essential component of this must be the monadological structure of the world. Each of these theories is an intermediate stage between solipsism and (contradictory) objective reality and perhaps has the structure of monadology, i.e., there is no objective reality, but only the different world views of the monads, between which there are lawful connections." (in: Lethen & Passon 2021, p.109)

- Move from Kant's epistemology to a Leibnizian ontology...
- ...and to a relational interpretation of Quantum Mechanics?!

➤ No conclusions... many questions...

Thank you for your attention!

References:

- Barrow, John D. (2022): Gödel and Physics. In: In: M. Baaz et al. (eds.), *Kurt Gödel and the Foundations of Mathematics: Horizons of Truth*. Cambridge University Press.
- Falkenburg, Brigitte (2020): *Kant's Cosmology. From the Pre-Critical System to the Antinomy of Pure Reason*. Cham: Springer Nature.
- Falkenburg, Brigitte (2004): Experience and Completeness in Physical Knowledge: Variations on a Kantian Theme. In: . Meixner & A. Newen (eds.), *Philosophiegeschichte und Logische Analyse / Logical Analysis and History of Philosophy*, Vol. 7. Paderborn: Mentis 2004, 153-176.
- Kant, Immanuel (1783): *Prolegomena*. Quoted after: *Theoretical Philosophy after 1781* (ed. by H. Allison & P. Heath), Cambridge University Press 2002.
- Lethen, Tim, & Oliver Passon (eds.) (2021): *Kurt Gödels Notizen zur Quantenmechanik. Transkriptionen und Kommentare*. Berlin: Springer Spektrum.
- Mittelstaedt, Peter (1998): *The Interpretation of Quantum Mechanics and the Measurement Process*. Cambridge: Cambridge University Press.
- Perales-Eceiza, Álvaro, et al. (2025): Undecidability in physics: A review. *Physics Reports* 1138,1-29.
- Scheibe, Erhard (1991): General Laws and the Uniqueness of the Universe. In: *Philosophy and the Origin and Evolution of the Universe*. E. Agazzi & A. Cordero (eds.). Dordrecht: Kluwer, p. 341 ff.; repr. in: E. Scheibe, *Between Rationalism and Empiricism. Selected Papers in the Philosophy of Physics*. Ed. by B. Falkenburg. New York: Springer 2001, 276-288.
- Zwick, Martin (1978): Quantum measurement and Gödel's proof. *Speculations in Science and Technology*, 1(2), 135-145.

