Notes from the underground

Mikhail Katz, Bar-Ilan University

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Human activity

Joint work with Karl Kuhlemann and David Sherry.
Over the past 16 years or so, our group has been publishing articles on the history, mathematics, and philosophy of infinitesimals.
We have over 80 articles in journals ranging from *Erkenntnis* to the *British Journal for the History of Mathematics*, and from the *Journal of Symbolic Logic* to *The Mathematical Intelligencer*.
These can be consulted at
`https://u.cs.biu.ac.il/~katzmik/infinitesimals.html`

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Remark (It's only human)

Doing both mathematics and the history or philosophy of mathematics is a human activity and as such is subject to opinions and prejudices of their practitioners.

Originally the hope was that professional historians and philosophers of mathematics would take an interest in our investigations and/or engage in meaningful debate.

Scathing

Even though our investigations challenge the received narrative of the past 350 years of the history of mathematics, the hope was for some meaningful feedback based on the fact that we have been publishing in a number of leading professional journals. The feedback started coming in the past several years, and it has been mostly scathing (with some notable exceptions). We have faced institutional and academic resistance to our interpretation of the history of infinitesimals, including attempts to discredit our work.

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Conclusion (Old boys' club)

The inescapable feeling about what is going on is that it is a standard example of dogmatic resistance to change and protecting the old boys' network.

This brought with it the realisation that some historians and philosophers are less interested in the truth than in propping up a party line.

Leibniz vs Ishiguro's stenographic narrative

One major challenge to the received narrative concerns the status of the Leibnizian calculus. What appears to be currently the received dogma is the *syncategorematic interpretation* of Leibnizian infinitesimals. This amounts to the claim that the term *infinitesimal* does not refer. In plain language, the claim means that whenever Leibniz used the term **infinitesimal**, he meant it as a kind of stenographic shorthand or placemark for proof by exhaustion using purely Archimedean terms.

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Remark (The term infinitesimal does refer)

Such a narrative has been refuted many times over, originally by Leibniz himself in a pair of 1695 texts, where Leibniz made it clear that his 'incomparable' infinitesimals violate the property formulated in Euclid (Book V, Definition 4) when compared to 1*. According to Leibniz, the term infinitesimal refers to a mathematical entity.*

Euclid V.4

In the edition Leibniz was using, the property appears as Definition 5. The definition is usually translated as follows:

> *Magnitudes are said to have a ratio to one another which can, when multiplied, exceed one another. (Euclid, Book V, Definition 4)*

The property expressed in Definition 4 is closely related to what is known today as the *Archimedean property*.

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Conclusion (Sound of building collapsing)

If Leibnizian infinitesimals violate the Archimedean property, they cannot be merely a placemark for an exhaustion argument in a purely Archimedean context.

Furthermore, while Leibniz occasionally mentions a 'syncategorematic infinity', he never speaks of 'syncategorematic infinitesimals' in any of his texts available thus far.

Contradicted his own work

Possible reasons why some historians and philosophers would cling to such a deficient stenographic reading are explored below.

But propping up the stenographic narrative (a.k.a. the syncategorematic interpretation) was apparently so important that one of the authors of a recent broadside against our work (see below) actually contradicted his own Leibniz scholarship.

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Remark (It had to be done)

Historian Doug Jesseph contradicted what he wrote in his own publications on this issue; see below.

The status of infinitesimals in the work of

Fermat, Euler, Cauchy and others

is hotly disputed, as well; see the url mentioned earlier.

Laugwitz

Detlef Laugwitz (1932–2000) was a mathematician and historian of mathematics, who published what became the standard biography of Bernhard Riemann in 1996.
He authored a series of publications in professional history of science and history of mathematics journals on both Euler and Cauchy. Laugwitz wrote:

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He authored a series of publications in professional history of science and history of mathematics journals on both Euler and Cauchy. Laugwitz wrote:

> *In the realm of the finite it does not really matter mathematically whether we consider the natural numbers as [1]* **ordinals** *or as [2]* **cardinals** *or as constituents of an [3]* **algebraic structure**.
> *Cantor had succeeded in showing, by different laws holding for transfinite ordinals and cardinals, that the infinite could clarify the conceptual distinctions. (numerals added)*

How are Stolz, Veronese and Levi-Civita different?

Ringinals

Laugwitz continues:

> *To Stolz, Veronese and Levi-Cività we owe early insights in ordered mathematical structures as a* **third aspect** *of the number concept.*
> *This approach prepared the ground for twentieth century developments. (Laugwitz 2002)*

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Remark (Third aspect of the number concept: algebraic structure)

Such a 'third aspect' is what we have referred to as a **ringinal** *in our recent publications. This can be defined as a number bigger than any naive counting number. The inverse of a ringinal is infinitesimal.*

Centuries before Levi-Civita (mentioned by Laugwitz), such entities were already in Leibniz; more specifically, in his 1676 manuscript *De Quadratura Arithmetica*, in the *Scholium* following Proposition 11.

Infinita terminata

Here Leibniz introduces a distinction between

- *linea infinita terminata* and
- *linea infinita interminata*

(literally: 'bounded infinite lines' and 'unbounded infinite lines'). Traditional mathematical training tends to foster a belief that there are only two legitimate forms of infinite number: *cardinal* and *ordinal*.

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Following Laugwitz, we will explore a trichotomy of

1. *cardinal*,
2. *ordinal*, and
3. *ringinal*.

The Leibnizian *infinitum terminatum* behaves as a *ringinal*. The *infinitum interminatum* is contradictory if taken as an infinite whole, and can only be made sense of syncategorematically (via Aristotelian potential infinity); see Ugaglia–Katz (2024).

De Quadratura Arithmetica

Richard Arthur and David Rabouin are among the signatories of a recent broadside against our work (see below).

Remark (Comical)

The most comical aspect of the Arthur–Rabouin production is their blatant cherry-picking when it comes to Leibniz's 1676 manuscript

De Quadratura Arithmetica (DQA).

It is instructive to compare their treatment of Proposition 6 and Proposition 11 of DQA.

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It is instructive to compare their treatment of Proposition 6 and Proposition 11 of DQA.

While commenting on Proposition 6, which they claim to be a triumph of the Archimedean method, they defend DQA fiercely against what they perceive to be insufficient appreciation by Jesseph and others.
But consider their attitude toward DQA's Proposition 11.

Proposition 11

Proposition 11 develops the dichotomy of

1. *infinitum terminatum* (literally: bounded infinity) vs
2. *infinitum interminatum* (literally: unbounded infinity).

Leibniz emphasizes that the *interminatum* is contradictory whereas the *terminatum* is not and therefore useful in geometry.

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Leibniz emphasizes that the *interminatum* is contradictory whereas the *terminatum* is not and therefore useful in geometry.

Remark (In modern terms)

In modern terms, Leibniz's unbounded infinity can be exemplified by an infinite line we take for granted today.

Meanwhile, bounded infinity is exemplified, in modern terms, by an interval of length H, where H is a nonstandard integer as formalized in Abraham Robinson's nonstandard analysis.

Conclusion

When it comes to Proposition 11, the Arthur–Rabouin team keeps mostly silent.

Types of impossibility

What Leibniz wrote in his Scholium to Proposition 11 directly refutes their central thesis concerning an alleged contradictory nature of *infinita terminata*; see Katz–Sherry–Ugaglia (2023).

Remark (Absence in nature)

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Here Leibniz observes that, though it may be impossible to find bounded infinities in nature (*rerum natura*), their usefulness to the **geometer** is independent of the **metaphysician's** task of elucidating their relation to natural phenomena:

> *"Determining whether nature warrants quantities of this type is the business of the Metaphysician; for the Geometer it shall suffice to demonstrate what follows from their supposition." (Leibniz)*

Metaphysician and geometer

("An autem hujusmodi quantitates ferat natura rerum Metaphysici est disquirere; Geometra sufficit, quid ex ipsis positis sequatur, demonstrare." Leibniz 1676)

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Remark (Varieties of impossibility in Leibniz)

On varieties of impossibility in Leibniz:

accidental impossibility and absolute impossibility,

see below.

An academic echo chamber

Historian Tom Archibald happens to be the first-mentioned author of a 9-author cartel whose driving force was Rabouin, which published a 3-page broadside against our article on Leibniz in *The Mathematical Intelligencer* in 2022.

Remark (Academic echo chamber participants)

The participants of this particular echo chamber are Archibald, Arthur, Ferraro, Gray, Jesseph, Lützen, Panza, Rabouin, Schubring.

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The title of the broadside is quite something:

> *'A Question of Fundamental Methodology: Reply to Mikhail Katz and His Coauthors'.*

Here one reads: "Leibniz's main argument is that it is not possible to treat infinitesimals as existing entities because that amounts to the introduction of an infinite number, which he takes to be a contradictory notion" (Archibald et al. 2022)

Alignment with Arthur–Rabouin

But such a reading of Leibniz aligns only with the Rabouin–Arthur narrative, according to which "infinitesimals, like infinite wholes, cannot be regarded as existing because their concepts entail contradictions" (Rabouin–Arthur 2020)

Actually what Leibniz held to be contradictory are 'infinite wholes', which is only one of the possible meanings of the term *infinite number* in Leibniz. A different meaning was developed by Leibniz in his *De Quadratura Arithmetica* and elsewhere.

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This is the *infinitum terminatum*, a type of 'infinite number' that was further developed by late 19th century scholars like Levi-Civita, as pointed out by Laugwitz (see the Section on Laugwitz above). For the Leibnizian distinction between *infinitum terminatum* and *infinitum interminatum*, see above.

Conclusion

Both the infinita terminata and infinitesimals are fictional non-contradictory notions.

Misrepresentations

Conclusion (Archibald's equivocation)

Archibald et al.'s claim about the contradictoriness of 'infinite number' involves equivocation on the meaning of the term.

Archibald et al. go on to manufacture a series of misrepresentations of our work, as when they claim that

> *"Nonstandard techniques of the kind invented by Robinson were presented [by Katz and coauthors] as a way to extend the realm of fictions related to infinite cardinalities by dealing with them in a consistent logical theory."*

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Archibald's claimed connection between fictional infinitesimals and infinite cardinalities is inaccurate. The latter (which would have been rejected by Leibniz as contradicting the part-whole principle which he viewed as axiomatic) are not necessary for developing a theory of infinitesimals. Archibald's claim hinges upon the flawed Rabouin–Arthur contention that infinitesimals were contradictory.

Argentina

Question

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The year after Rabouin and Arthur published their syncategorematic take on Leibniz in the *Archive for History of Exact Sciences* in 2020, an Argentinian team (Esquisabel and Raffo Quintana) published, in the same journal, a perceptive study of Leibnizian calculus.
Their study contains an explicit refutation of Rabouin and Arthur, though in passages hidden well in the middle of their text.
Specifically, they reject the interpretation of Leibnizian infinitesimals as contradictory.

Arthur

Philosopher Richard Arthur is a veteran syncategorematist; see e.g., his

> *"Leibniz's syncategorematic infinitesimals" (Arthur 2013).*
>
> *"Leibniz's syncategorematic infinitesimals II: their existence, their use and their role in the justification of the differential calculus" (2020)*

As late as 2024, Arthur is still committing short-sighted errors of interpretation to prop up the stenographic narrative he inherited from (Ishiguro 1990).

Bos

Historian Henk Bos is the author of a seminal 1974 article on Leibniz. Bos also commented on the issue of interpreting the Leibnizian calculus in Abraham Robinson's framework called *Nonstandard Analysis*. Here on page 13 Bos wrote:

> *A preliminary explanation of why the calculus could develop on the insecure foundation of the acceptance of infinitely small and infinitely large quantities is provided by the recently developed* **non-standard analysis**, *which shows that it is possible to remove the inconsistencies without removing the infinitesimals themselves. (emphasis added)*

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This comment appears to endorse in principle the idea of using modern infinitesimal analysis to clarify some problems with the Leibnizian calculus.

Walking back

Meanwhile, Bos' Appendix 2 starts 68 pages later and tends to walk back the tentative endorsement of page 13.

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Remark (Not a trace)

One thing is certain, however: Bos' seminal article on Leibniz contains not a trace of syncategoremania.

Given the recognized seminal nature of Bos' study, this a huge problem for syncategorematists of Rabouin's ilk.

The writings of Arthur and Rabouin contain only lame attempts to explain this away by means of far-fetched readings of Bos.

Probst

Historian Siegmund Probst is one of a handful of Leibniz scholars working on the Academy edition of the complete works of Leibniz; see `https://leibnizedition.de`. Here is Probst's question:

Question (Probst's question)

The question is whether Leibniz based his metaphysical foundation of the calculus wholly on the concept of the syncategorematic infinite or whether he pursued also an alternative approach of accepting infinitesimals similar to what is done in modern nonstandard analysis. (Probst 2018)

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Then he notes in a footnote: "Opposing views are stated in, e.g., Arthur (2013), *Leibniz's syncategorematic infinitesimals*; Sherry and Katz (2012), *Infinitesimals, imaginaries, ideals, and fictions*."

Leibniz historian Probst evidently is willing to contemplate alternatives to the syncategorematic narrative.

Dauben

Joseph Dauben is a historian of mathematics and the author of several well-received books and numerous articles. Dauben asks:

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Answer (Dauben's answer)

Robinson succeeded in showing the reasonableness of 'redrawing' the early history of the calculus to reinstate past views that, cast in the light of nonstandard analysis, could be seen more clearly. . . . an anachronistic explanation nevertheless serves to clarify, not confound, what had confused earlier defenders of theories based on infinitesimals like the calculus.

Procedures versus foundations

While Dauben's appreciation of the clarifying role of nonstandard analysis (NSA) as applied to the history of the calculus is refreshing, it is important to note that there is nothing anachronistic about relying on NSA to clarify the *procedures* of the historical infinitesimalists, as opposed to *foundational* issues involved in how exactly such procedures are to be formalized.

Conclusion (Comparison of frameworks)

Applying a Robinsonian framework to this end is no more anachronistic than applying the more traditional Weierstrassian framework to this end.

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Both post-Weierstrassian classical analysis and infinitesimal analysis à la Robinson are grounded in set-theoretic *foundations* which in themselves shed no light on the thinking of Leibniz, Euler, Cauchy and other infinitesimalists. But the *procedures* of NSA provide closer proxies for their procedures than the traditional post-Weierstrassian procedures.

Closing remark

Remark (Syncategorematic scotch)

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They sit down and order a round of top-shelf scotch.
The bartender nods, walks over, and places three completely empty glasses on the counter.

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The bartender nods, walks over, and places three completely empty glasses on the counter.

Arthur looks confused, but Rabouin waves his hand reassuringly and says: 'No, no, Richard, it's fine.
The scotch is syncategorematic.
The terms on the menu do not actually refer to an existing liquid.
It is simply a placemark for a long-winded, exhausting Archimedean process of distillation!'

They all raise their empty glasses, toast to Archimedes, and leave the bartender a purely fictional tip.

Postscript

Remark (Best of all possible worlds)

After Rabouin gets a 3 million euro grant from the EU, Arthur and Rabouin procure a time-travel machine, travel back to Hanover in the year 1690, and track down Leibniz in a local tavern. They slam a copy of 'Ishiguro 1990' (along with some of their own work) onto the table, and proudly declare: "Gottfried! We did it!
We've finally shown that you were misunderstood for centuries. Whenever you used the contradictory term 'infinitesimal quantity,' it was, of course, merely shorthand for a cumbersome Archimedean formulation. What a genius you are!"

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Leibniz looks at the book and sighs deeply. 'Gentlemen,' Leibniz says, 'I am a co-inventor of calculus, a pioneer of the binary system, and a philosopher who believes this is the best of all possible worlds. But these 21st-century fellows must be completely mad. I'm beginning to doubt that this is the best of all possible worlds.'

THANK YOU!

Exhibit A: Scatterbrain monstrosity

Antoni Malet was an Editor-in-Chief of the journal *Historia Mathematica* when one of our articles on infinitesimals was submitted there.
He was President of the European Society for the History of Science from 2016 to 2018.
Malet found it appropriate to forward to us a referee report whose conclusion is worth quoting in full (reproduced verbatim including spelling errors):

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Malet found it appropriate to forward to us a referee report whose conclusion is worth quoting in full (reproduced verbatim including spelling errors):

> *"I was about to call the manuscript a slapdash collection of bits and pieces randomly strung together. But that would be too generous. The authors have not even attempted to string their* **scatterbrain** *thoughts together. The have merely placed a bunch of random scraps adjacent to each other and submitted the resulting* **monstrosity** *as a research article." (referee report, 4 august 2024)*

Exhibit A cont.

Recall that this is a referee report for what is supposed to be a serious scholarly publication venue.

Remark (Scatterbrain monstrosity in BJHM)

The 'scatterbrain monstrosity' in question went on to be published in the British Journal for the History of Mathematics.

Exhibit A cont.

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Here is the full reference:

> *Katz, M. Episodes from the history of infinitesimals. British Journal for the History of Mathematics* **40** *(2025), no. 2, 123–135.*

The decision at the *British Journal for the History of Mathematics* was based on detailed and favorable referee reports.
This is the third article by our group that was published in the *British Journal for the History of Mathematics*.

Exhibit B: Banish the error and confirm that Cauchy had used hyperreals

Gert Schubring is the last-mentioned member of the cartel of 9. Schubring's book contains scathing attacks against the remarkable scholarship of historian Detlef Laugwitz (see the Section on Laugwitz) published in leading history of mathematics and science journals, as well as mockery of nonstandard analysis as an interpretive tool. Thus, Schubring writes:

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> *Detlef Laugwitz . . . has been analyzing Cauchy since the 1980s with the goal of ruling out every attribution of error to his work. In a discussion with Pierre Dugac in 1986, he formulated his maxim as follows: Cauchy was such a great mathematician. Everything else he did was correct. Therefore, when faced with a choice between two possible interpretations of his concepts, one has to go for the one that makes his proof correct. In 1984, Giusti published a decisive article on Cauchy's 'errors' . . .*

Exhibit B cont.:

Schubring continues:

> *This spurred Laugwitz to even more detailed attempts to* **banish the error and confirm that Cauchy had used hyper-real numbers**. *On this basis, he claims, the errors vanish and the theorems become correct, or, rather, they always were correct (see Laugwitz 1990, 21). (Schubring 2005, p. 432)*

This sarcastic slapdash is a caricature of Laugwitz's position and in particular of page 21 in his 1990 article cited by Schubring, as we demonstrated in our critique of Schubring's approach; see Błaszczyk et al. (2017).

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This sarcastic slapdash is a caricature of Laugwitz's position and in particular of page 21 in his 1990 article cited by Schubring, as we demonstrated in our critique of Schubring's approach; see Błaszczyk et al. (2017).

Contrary to Schubring's claim, Laugwitz never asserted that Cauchy had used the hyperreals. Furthermore, Laugwitz **never asserted** that "errors vanish". Rather, he noted that in 1853, Cauchy strengthened the hypothesis of his erroneous 1821 theorem.

Dostoevsky

Remark (Prestupleniye i nakazaniye)

To the orthodox establishment, suggesting that Leibniz took actual infinitesimals seriously isn't just a misreading; it's **Crime and Punishment**. *The 'Crime' is submitting the paper, and the 'Punishment' is what Malet's referee did to it.*

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Remark (Besy)

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Remark (Brat'ya Karamazovy)

In **The Brothers Karamazov**, *Ivan famously declares that he has a 'Euclidean mind' that cannot grasp non-Euclidean concepts. I suspect the dominant Leibniz establishment suffers from a similar condition: an 'Archimedean mind' that physically recoils at the sight of a hyperreal continuum.*