

Linking Is the Latch

Reading the integer on a linked filament, and why a bare filament sets no floor

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License: Creative Commons Attribution 4.0 International (CC BY 4.0) A checkpoint from an ongoing holonomy-instrument program — a point on a road, not a finished result.

Version 2 withdraws the energy-floor measurement of version 1. The energy of the linked filament pairs did climb as the linking rose, and every number in version 1’s text and ledgers reproduces to the digit. But the climb was the length of rope the starting shapes were built with, and the filament energy used here has no floor at all. Version 1 also read a result of Freedman and He as a three-halves growth law, which it is not. The reader and its integer stand. Every change is listed in “What changed in version 2”.

The claim

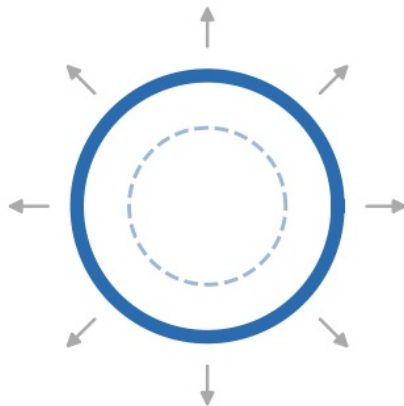
Closure lets a loop count. Linking lets it lock.

A single ring, unknotted and unlinked, holds nothing for long. It carries energy and then loses it at whatever rate its medium allows — a bucket with a slow hole, not a battery. Nothing in its shape forbids the leak; a bare loop has no floor beneath its energy at all, only the slowness of whatever is draining it.

Two rings threaded through each other are a different kind of object. The number of times one passes through the other is an integer, and an integer cannot be spent a little at a time. It is one, or it is two, or it is zero, and there is no value in between for the energy to slide down through. To change it you must cut. That indivisibility is a latch. It does not itself store energy — it is a number, not a reservoir — but in a medium that carries the rings as tubes of fixed flux and fixed volume, it forbids the reservoir from emptying below a floor that the integer sets. The store is the substrate; the integer is the lock on the door.

This paper builds an instrument that reads that integer directly and watches it refuse to move when the shape is deformed. It then reports what happened when the same instrument was used to look for the floor in a model made of bare curves: the energy climbed with the integer, and the climb turned out to be something else. The model has no floor to find, and the paper says why.

unlinked ($Lk = 0$)
a bucket with a hole



linked ($Lk = 1$)
the integer is the latch

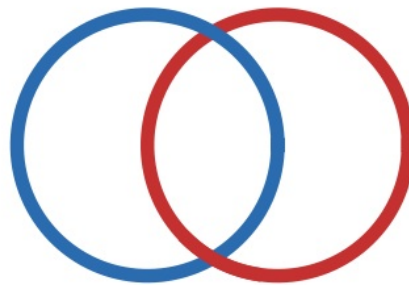


Figure 1. *Two rings, two fates. A single unlinked ring (left) has no floor beneath its energy; it drains at whatever rate its medium allows, a bucket with a slow hole. Thread two rings through each other (right) and their linking number is an integer that no smooth motion can change, a latch that, in a tube of fixed flux and volume, forbids the store from emptying below a floor the integer sets.*

One family, wound tighter: torus knots as a curve on a torus

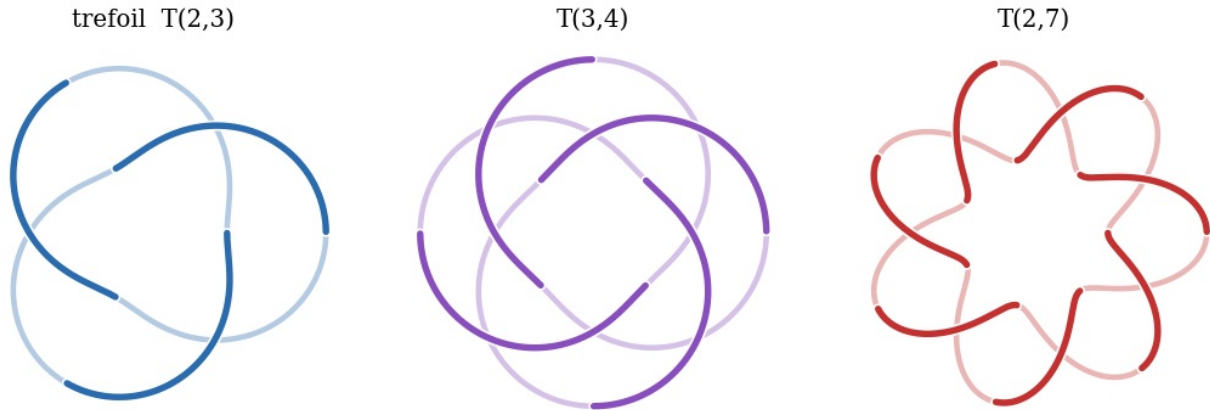


Figure 2. *The objects themselves. A torus knot is a single closed curve wound on the surface of a torus, so many times the long way and so many times around the tube. The linked pairs in this paper are cousins in the same family: two closed strands on one torus, each going once the long way and m times around the tube, so that the two strands link m times.*

What is already known, and what this adds

The existence of a floor is not new, and this paper does not claim it. That the energy of a magnetic field frozen into a perfectly conducting fluid is bounded below by a quantity set by its topology and its size is Arnold's inequality, and the identification of that topological quantity, the helicity, with the linking of the field lines is Moffatt's. For two thin linked flux tubes the helicity is twice the linking number times the product of the two fluxes (Moffatt and Ricca), so this floor grows in proportion to the integer. Freedman and He proved a floor of a second kind, one that needs no linking number at all: the ordinary energy of a unit-flux field in a knotted or linked tube is bounded below by a constant times the tube's asymptotic crossing number, divided by the cube root of its volume. The asymptotic crossing number is a count of crossings that Freedman and He define for the knot or link the tube follows, and they bound it from below by twice the knot's genus minus one and, for a link, by a Thurston norm. On the way they bound a companion quantity they call the $3/2$ -energy, the integral of the field strength raised to the power three-halves. There the three-halves is the name of an energy; where a three-halves power does appear as a law, it bounds the shape of the tube, not its energy. Moffatt argued that every knot and link has an "energy spectrum", a set of positive numbers fixed by its topology (and, in his construction, by the twist of the field inside the tube), whose lowest member measures its complexity. Moffatt and Ricca gave the helicity of a knotted tube through Călugăreanu's theorem, linking equals writhe plus twist, and, following Moffatt's procedure, showed how helicity is written by cutting: cut the tube, twist the free ends through whole turns, and reconnect, or switch a crossing, each switch adding or removing a fixed amount. Linked and knotted vortices have been tied experimentally in water by Kleckner and Irvine. The floors, and the arithmetic of writing them by cutting, are theirs.

What this paper offers against that background is narrow: an instrument that reads the linking integer directly from a curve and checks that it holds while the curve is deformed, and a negative result about the model it was first used in. A filament model, in which closed curves carry a fixed current around a fixed thin core, sets no energy floor at all. The floors above live in a tube of conserved flux and volume, and the filament model has no tube. Version 1 missed this and reported a floor; this version withdraws that measurement and shows where it came from.

The instrument

Start with the picture. Imagine two rubber bands looped through each other. You want a machine that looks at the tangle and answers one question: how many times does one band pass through the other? That count is the whole game, because it is a whole number and a whole number cannot leak away a little at a time.

A filament is a closed curve, carried in the computer as a loop of points. The reader is the discrete Gauss linking integral between two such loops, and the writhe integral for a single one — both are sums over pairs of segments of a simple geometric kernel, and in words each asks the same question the eye asks of a tangle: going all the way around, how many times did this thread pass through that one, counting sign. The Gauss integral is Ampère’s law read backwards: walk the second loop and add up the part of the magnetic field, made by a current in the first loop, that points along the walk, and the total counts how many times the current threads the walk. That walk-and-add around a closed loop is what makes it a holonomy reader. Evaluating these integrals numerically on a curve of points is standard practice, in DNA topology among other places (for example Klenin and Langowski); nothing in the reader is new except where it is carried.

A number earns the name “topological” only if it survives a change of instrument. A magnitude dressed as an integer will drift when the ruler changes; a true invariant will sit still. So the first test is not physics but trust: refine the loop and watch whether the reader converges onto a whole number or wanders.

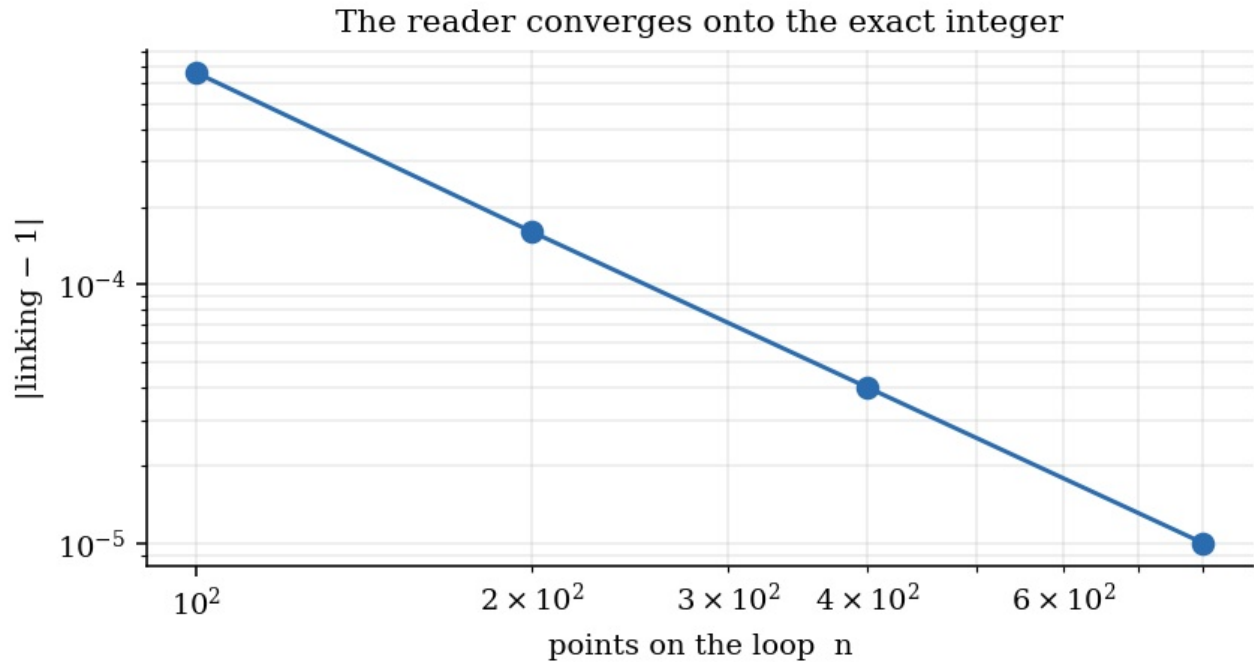


Figure 3. *The reader converges onto the exact integer. The linking of a Hopf link, read at rising resolution, approaches magnitude one as the loop is refined (it reads -1 ; the sign records the orientation of the two loops, and the error plotted is how far the magnitude sits from one), and the error falls as the inverse square of the point count. A continuous quantity converges too, but not onto a whole number.*

Measured, the linking of a Hopf link reads -1.00066 , -1.00016 , -1.00004 and -1.00001 as the loop is refined from 100 to 800 points: the error falls about fourfold each time the point count doubles, converging onto the integer, not drifting from it. The sign is the orientation of the two loops; the count is one. A pair of far-apart, unthreaded circles reads 0.00000. The same kernel applied to a single trefoil gives its writhe, -3.3572 , -3.3549 and -3.3543 at 200, 400 and 800 points. That converges too, but onto -3.354 , which is not a whole number, because writhe is geometric: in Călugăreanu’s theorem writhe and twist are the two continuous halves that trade against each other, and only their sum, the linking, is an integer. The trefoil row is a check on the kernel, not a topological reading. Convergence onto a whole number under refinement is what the linking reading has and the writhe reading lacks, and it is the property against which the rest of this paper is anchored.

The latch: linking cannot be shrunk away

If the linking is a real integer, then no smooth deformation can change it, because a smooth deformation cannot pass one strand through another. The cheapest picture of this is to take a linked pair and shrink it, both loops and the gap between them together, and watch the integer.

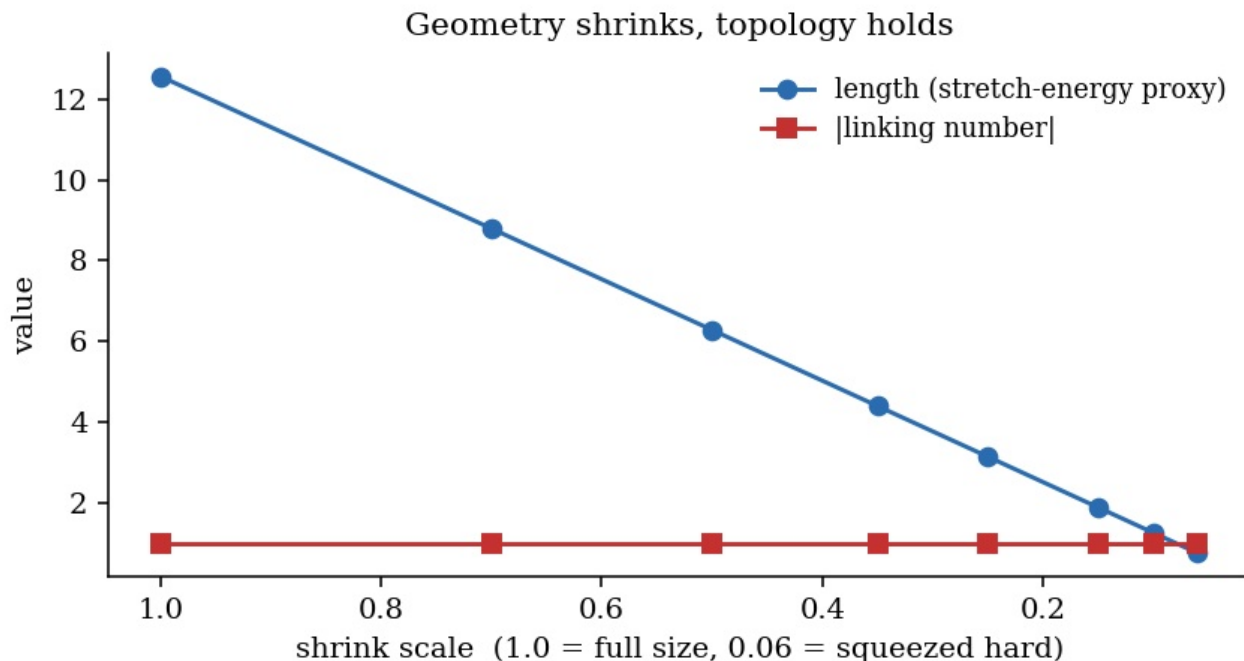


Figure 4. *Geometry shrinks, the count holds. As a linked pair is shrunk, its length falls toward zero while its linking number stays at magnitude one the whole way down. A uniform shrink cannot change a Gauss integral, so the flat line shows the reader behaving, not the latch working; the falling line shows that nothing in a bare curve stops it shrinking.*

The length falls in proportion to the scale, from 12.57 to 0.75 over a 16.7-fold shrink, while the linking reads -1.0000 at every step. Two cautions keep this honest. First, a uniform shrink is a change of scale, and the Gauss integral does not see scale: it would read the same in any model, so this test checks the reader, not the latch. The relaxations in the next section test it little more. They move each point separately, but the largest move of any point is 0.11 in the crude relaxation and 0.24 in the stronger one, while the two strands never come closer than 0.59; no strand could have passed through another, and the linking read the same before and after every relaxation. A real test of the latch needs a move that could cut, and a rule for what then happens, which is the reconnection wall named below. Second, the shrink shows what a bare curve lacks. Its length can be made as small as we like while the count stays put, and its bending grows as the scale falls (from 12.6 to 209.4 in the bending measure used), so neither measure sets a floor tied to the integer. The count is locked; nothing in a bare curve says what the lock is holding back.

What the energy runs measured, and why it is not a floor

Version 1 asked a plain question: if two loops are linked more times, does the lowest energy they can reach rise? It built pairs linked once to six times, relaxed each, and read off how the energy rose. The energy rose. The rise is real and it reproduces to every printed digit; what it measured was not a floor.

The pairs are two strands on one torus of fixed size, with radii 2 and 0.6, each strand winding m times around the tube. Winding more times on the same torus takes more rope: each strand is 13.14 long at linking one and 25.93 at linking six, against 12.57 for each circle of the unlinked reference. The energy is the magnetic energy of a unit current carried along each curve around a fixed core of radius 0.05, the standard filament form, and most of it is each strand's own energy, which grows with the strand's length. Its values are not converged in the point count: the

starting energy of the pair linked six times is 17.51 at 160 points per strand and 16.38 at 1280, and the starting energies rise with the linking at every point count checked while their digits move. Relaxation was done two ways. A crude relaxation moved one point at a time by small random steps, keeping each move only if it lowered the energy (160 points per strand, best of three seeds, 900 moves). A stronger one moved every point at once down the energy gradient, with a spring pulling each segment toward its starting length (72 points per strand, 60 steps). The linking was read before and after each relaxation; no constraint held it.

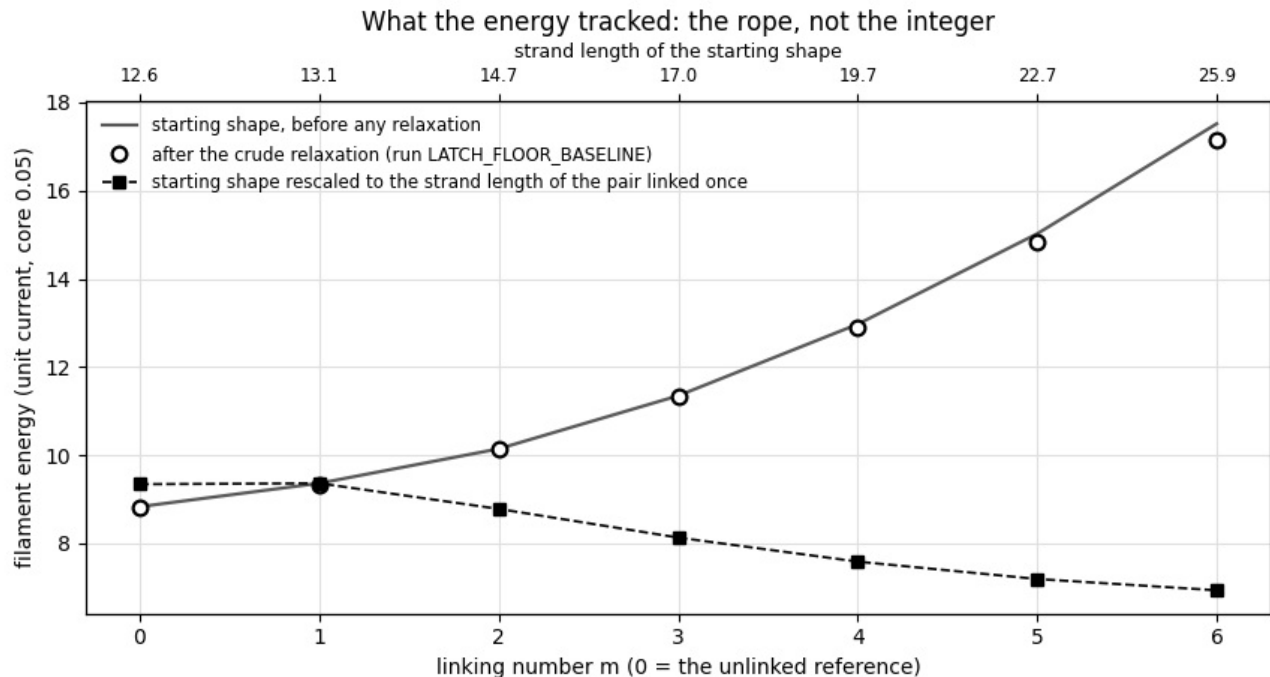


Figure 5. *What the energy tracked. After the crude relaxation (open circles) each pair sits on the energy of its own unrelaxed starting shape (solid line): the relaxation moved it by 0.1 to 2.1 percent. The starting strands grow longer as the linking rises (top axis). Rescaled so that every pair has the strand length of the pair linked once (squares), the starting energy falls as the linking rises. The climb reported in version 1 was the rope, not the integer.*

The crude relaxation reproduces version 1's staircase exactly. The unlinked reference relaxes to 8.82 and the linked pairs to 9.34, 10.13, 11.33, 12.91, 14.84 and 17.15, so the excess over the reference is 0.52, 1.32, 2.51, 4.09, 6.02 and 8.33. Three checks on the same energy and the same shapes say what that staircase is.

The first check is the unrelaxed shapes. Before any relaxation the same pairs already sit at 9.36, 10.14, 11.35, 12.97, 15.02 and 17.51, with the reference at 8.83. The crude relaxation lowered each energy by 0.1 to 2.1 percent, and the excess before relaxation is between 99.7 and 104.3 percent of the excess after it. A power law fitted to the excess gives $m^{1.554}$ after relaxation and $m^{1.565}$ before it: the exponent belonged to the starting shapes.

The second check splits the energy. Of the rise from the reference to linking six before relaxation, 8.68 in all, 6.70 (77 percent) is the two strands' own energy, which depends only on each strand's shape and length, and 1.98 is the cross term between them.

The third check holds the rope fixed. Rescaled so that every strand has the length of the strand linked once, 13.14, the starting energy falls as the linking rises: 9.36, 8.78, 8.13, 7.59, 7.19 and 6.94 for linking one to six, with the unlinked reference at 9.34. And the pair linked six times, shrunk to half size so that its strands are 12.97 long, has energy 6.81 with its linking still reading 6.033: below the unlinked reference at 8.83, and below every relaxed pair in the table.

So the filament energy used here has no floor tied to the integer. For these shapes, holding the rope fixed makes the energy fall as the linking rises, and any pair can be made cheaper still by shrinking it. The staircase in version 1 was the rope that the torus construction lays down, which grows with the winding, read through an energy dominated by each strand's own length.

The stronger relaxation does not change this. It relaxes further, 7 to 34 percent below its own starting shapes, and its excess climbs 0.65, 1.48, 2.54, 3.63, 4.76 and 6.05, a fitted $m^{1.25}$. But its spring pulls every segment back toward its starting length, so the strands shorten only partly and stay long in proportion to the winding: after relaxation they run from 12.0 at linking zero to 19.2 at linking six, having started at 12.6 and 25.7. At its 72 points per strand the starting energy of the pair linked six times is 22.37, against 16.38 at 1280 points, so the coarse curve begins well above the converged value and part of the stronger relaxation's drop is that gap closing. It also differs from the crude run in three ways at once, the minimizer, the point count and the spring, and at linking one and two it ends further above its reference than the crude run does, not closer (excess 0.6475 against 0.5196, and 1.4810 against 1.3165). Version 1 read the gap between $m^{1.55}$ and $m^{1.25}$ as an exponent sliding with the strength of the relaxation. With three things changed at once that reading is not supported, and neither exponent measures a floor.

The runs, row by row:

Linking m	Strand length, starting shape	Energy, starting shape	Energy after crude relaxation	Excess after relaxation	Energy at strand length 13.14, starting shape
0 (unlinked)	12.57	8.83	8.82	0.00	9.34
1	13.14	9.36	9.34	0.52	9.36
2	14.72	10.14	10.13	1.32	8.78
3	17.00	11.35	11.33	2.51	8.13
4	19.72	12.97	12.91	4.09	7.59
5	22.74	15.02	14.84	6.02	7.19
6	25.93	17.51	17.15	8.33	6.94

Where a floor lives

The floors in the literature are floors on a field that fills a tube, not on a current that runs along a line. In a tube of fixed magnetic flux and fixed volume, frozen into a perfectly conducting fluid, the field lines cannot cross, the flux cannot leave, and the tube cannot shorten without growing fatter. The field's own tension pulls the tube shorter, so a linked or knotted tube tightens until its strands press against each other and can go no further, and that pressing is what lets the topology set a floor. This is the picture behind Moffatt's energy spectrum. How much tube a link needs at its tightest, its rope length, is studied directly as a problem in geometry: Klotz and Thompson, for example, build efficient non-alternating torus knots and links from concentric helices. The optimised rope length of their helices is about 7.83 times the three-halves power of the minor index, and the torus links made from them need about twelve times the three-quarters power of their crossing number. Those are upper bounds from a construction, on a rope length against an index of winding; they are not an energy law. The filament model has none of the tube. Its curves have no thickness to press, its core does not fatten as a curve shortens, and nothing stops two strands from lying on top of each other down to the scale of the core. The next instrument is therefore not a stronger relaxation of the same energy. It is the same reader carried into a tube model with conserved flux and volume and a thickness the strands cannot overlap, so that the linking can be read while the rope tightens.

The dial does not port

One warning before anyone gets excited. The lock — the fact that an integer cannot change without a cut — is the same in every material. But how *much* energy it holds back, for a given size, and whether it holds any back at all, is not. That is set by the material, and it has to be measured fresh each time. Borrow it from one material and use it in another and you will be wrong. The bare filament above is one case: the lock is there and it holds nothing. Here is another, where two media even point opposite ways.

A latch needs a guardrail, because "an integer sets a floor" sounds as though it should carry unchanged into every medium, and the hardest-won lesson of this program is that it does not. The lock is universal; the knob that sets how much energy the store holds per unit of size is re-bought in every medium and must never be assumed to transfer.

The persistent current of a ring lattice makes the point. Its amplitude — the store — falls as the ring grows, roughly as one over the circumference, while a vortex ring in water does the opposite: at held circulation its energy rises with radius. Same integer latch, opposite geometric dial, in two media that could not be more ordinary. The lock is the same object in both; the dial turns opposite ways, and reading one from the other would be the error the guardrail exists to catch. The precise scaling of the ring-lattice amplitude is reported and reproduced in the companion instrument suite, Instruments for the Magnetic Forest (10.5281/zenodo.22906780), rather than here, so this paper leans on the direction of the effect, not on a figure it does not re-derive.

What this is not

Four limits, stated plainly. The existence of an energy floor set by topology is Arnold’s, Moffatt’s, and Freedman and He’s; it is not measured here, and version 1’s measurement of it is withdrawn. The filament model used here sets no floor, as the energy runs show; that is a property of the model, and it says nothing against the floors proved for tubes. The shrink test and the relaxations check the reader and the minimizer, not the latch: neither could have cut a strand. And the reconnection wall stands where it stood: a pure filament code conserves the linking by construction, so this instrument cannot show a link untying. How helicity changes when a tube is cut, twisted through whole turns and reconnected, or when a crossing is switched, is worked out by Moffatt and Ricca; what this program still lacks is a cut-and-rejoin rule inside its own code, which would be the single largest assumption any untying result carried.

Falsifiable claims

claim	what would kill it	status
The linking reader returns a true integer	a refinement that drifts off the whole number	Hopf $-1.00066 \rightarrow -1.00001$ from 100 to 800 points; the error falls about fourfold per doubling
The linking reading is stable under the deformations used here	any shrink or relaxation that changes the reading	reads -1.0000 across a 16.7-fold uniform shrink; reads the same before and after every relaxation, to 0.001 in the crude run and 0.006 in the stronger one. Neither deformation could have changed it (a uniform shrink cannot, and no move came near the gap between the strands), so this row checks the reader, not the latch. The offsets from the integer at high linking are present before any relaxation and are smaller with more points: 0.033 at 160 points, 0.165 at 72
The filament energy sets a floor that climbs with the linking	—	WITHDRAWN in version 2: the climb is the starting rope length; at equal rope length the energy falls with linking ($9.36 \rightarrow 6.94$), and the pair linked six times at half size (6.81) sits below the unlinked reference (8.83)
The instrument, carried into a tube model of conserved flux and volume with a thickness, shows the energy at the tightest rope rising with the linking, as the proved floors require	no rise, which would indict the tube model or its relaxation, since the floors are theorems	OPEN — the next instrument
A link can be untied under a stated rule	—	OPEN — needs a cut-and-rejoin rule in the code; the helicity arithmetic of such cuts is Moffatt and Ricca’s

Appendix A — approaches evaluated and not pursued

A pure filament code to test untying. Attractive because it needs no grid and reads topology exactly. It cannot answer the untying question: with no reconnection rule the linking is conserved by construction, so the code would confirm the latch by building a machine that could not violate it. Untying needs an explicit cut-and-rejoin rule added by hand.

Length as the energy whose floor is measured. Used for the shrink picture. Length alone has no floor for a bare curve, and, as the energy runs show, neither has the magnetic energy of a current along it. A floor needs a tube with a thickness, a conserved flux and a conserved volume.

A stronger relaxation of the same energy. Tried in version 1. It relaxes further, but it cannot create a floor the energy does not have, and with its segment spring it holds on to the rope the construction laid down.

Reading the floor from a single linking value. A single minimum energy is a magnitude and says nothing on its own; the test that carries meaning is the staircase across integers. Version 2 adds the condition version 1 lacked: the staircase must hold the rope fixed across the integers, or it measures the rope.

Why keep a withdrawn measurement in the record

Because the mistake is instructive and easy to repeat. Version 1 compared an exponent from a filament run with an exponent it believed Freedman and He had proved, and read the rough agreement as evidence that the instrument was telling the truth. Both halves were wrong. The three-halves in Freedman and He names an energy; the floor they prove on the ordinary energy grows in proportion to the asymptotic crossing number. And the exponent measured here was set by how the starting curves were built. Two numbers that looked alike were connected before anyone asked what kind of object each one was, and an exponent's agreement with a theorem was taken as a check when neither side had been read closely. What survives is smaller and firmer: a reader that returns the integer to within 0.00001 at 800 points and converges on it as the loop is refined, a count that holds through every deformation the model makes, and a plain statement of what a bare filament lacks. That reader is what this program carries into the next substrate, and the tube model named above is where it goes first.

What changed in version 2

1. The energy-floor measurement is withdrawn. The climb of the relaxed energy with the linking is the starting rope length (runs `LATCH_FLOOR_BASELINE` and `LATCH_FLOOR_CONFOUND_CHECK`); the filament energy has no floor. Figure 5 is replaced, the table gains the strand length, the starting energy and the energy at equal rope length, and the claims table carries the withdrawal.
2. The Freedman and He attribution is corrected. Their three-halves names the $3/2$ -energy; their floor on the ordinary energy is proportional to the asymptotic crossing number. Version 1's sixth figure, "Three roads, one exponent", is removed, and so is every sentence that compared the measured exponent with a proved three-halves.
3. Klotz and Thompson's result is described as what it is, a rope-length construction, and not as a proof of an energy law.
4. The Hopf-link readings carry their sign, -1 , and the orientation is stated.
5. The trefoil's writhe is reported as a geometric check on the kernel, not as evidence of convergence onto an integer.
6. The shrink test and the relaxations are read as checks of the reader and the minimizer, not as demonstrations of the latch, and the energies' dependence on the point count is stated.
7. Version 1's Figure 5 image plotted an earlier run that was never deposited, while its caption gave the deposited numbers. The new Figure 5 is drawn from the deposited runs by a deposited script.
8. Credit added: Moffatt's energy spectrum of knots and links; Moffatt and Ricca's writing of helicity by cutting (Dehn surgery) and by crossing switches; Călugăreanu's name on the theorem linking equals writhe plus twist; Klenin and Langowski for numerical Gauss integrals. Schubert's prime decomposition is removed, since no claim rests on it and version 1 gave it the wrong year.
9. Tools: `latch_probe.py` prints the Hopf target as a magnitude and reads the shrink correctly (its numbers are unchanged); `latch_floor_fit.py`, new, makes the table and fit that version 1's ledgers carried by hand; `latch_floor_confound_check.py`, new, runs the checks above; every launcher now writes its ledger straight from the tools' own output.
10. A tool and computational resource disclosure section is added.

11. The files carry their final names.

Declaration

Peer review. This is a preprint and carries none.

Literature pass. Limited but targeted at the load-bearing claims, and read at the levels stated here. Read in full: Freedman and He, “Links of tori and the energy of incompressible flows” (Topology 30(2), 1991, 283–287); Moffatt and Ricca, “Helicity and the Călugăreanu invariant” (Proc. R. Soc. Lond. A 439, 1992, 411–429); Ricca and Moffatt, “The helicity of a knotted vortex filament” (in Topological Aspects of the Dynamics of Fluids and Plasmas, Kluwer, 1992, 225–236). Read in part, pages 220 to 229: Freedman and He, “Divergence-free fields: energy and asymptotic crossing number” (Annals of Mathematics 134(1), 1991, 189–229). Checked against the publisher record at the level of the abstract: Moffatt, “The energy spectrum of knots and links” (Nature 347, 1990, 367–369); Klotz and Thompson, “Ropelength-minimizing concentric helices and non-alternating torus knots” (Proc. R. Soc. A 481, 2025, 20250319); Maggioni, Alamri, Barengi and Ricca, “Velocity, energy, and helicity of vortex knots and unknots” (Phys. Rev. E 82, 2010, 026309), the filament computation of the energy and helicity of vortex torus knots by Biot-Savart integration, the same family of method as the energy used here; Kleckner and Irvine, “Creation and dynamics of knotted vortices” (Nature Physics 9, 2013, 253–258); Klenin and Langowski, “Computation of writhe in modeling of supercoiled DNA” (Biopolymers 54, 2000, from page 307). Cited through the papers read in full and not re-fetched: Arnold, “The asymptotic Hopf invariant and its applications” (1974; English translation Sel. Math. Sov. 5, 1986, 327–345); Moffatt, “The degree of knottedness of tangled vortex lines” (J. Fluid Mech. 35, 1969, 117–129); Călugăreanu (Rev. Math. Pures Appl. 4, 1959, 5–20; Czechoslovak Math. J. 11, 1961, 588–625), whose theorem that linking equals writhe plus twist carries his name here, as Moffatt and Ricca argue it should, rather than White’s (1969) or Fuller’s (1971). These are the ground this checkpoint stands on, not rivals. A wider pass may surface further adjacent work, and any such work is prior art to be credited, never a competitor. Any reader who knows of work this paper should have cited is asked to write.

Provenance. Every number names its run, and every run regenerates from the tool beside it in the deposit. Reader trust and the shrink: run LATCH_PROBE (latch_probe.py). The relaxed energies after the crude relaxation, their excess and fit: run LATCH_FLOOR_BASELINE (latch_floor_baseline.py in three pieces, then latch_floor_fit.py). The stronger relaxation: run LATCH_FLOOR_GRADIENT (latch_floor_gradient.py, then latch_floor_fit.py). Strand lengths, starting energies, the split of the energy, the energies at equal rope length, the half-size pair, the stronger relaxation’s strand lengths, the largest moves and closest approaches, and the energies at higher point counts: run LATCH_FLOOR_CONFOUND_CHECK (latch_floor_confound_check.py). Figure 5 is drawn by fig5_what_the_energy_tracked.py from the LATCH_FLOOR_CONFOUND_CHECK and LATCH_FLOOR_BASELINE run files. Figures 3 and 4 are carried unchanged from version 1 and plot the LATCH_PROBE numbers. The runs of version 1 were repeated for version 2 and reproduced to every printed digit. The ring-lattice direction in “The dial does not port” is carried from the companion suite (run RING_LATTICE_READER 20260914_032117 there); no figure or number from it appears here. No number here lives only in prose.

Dual use. This work concerns the energy of linked filaments, which is adjacent to magnetic reconnection and to the confinement of plasma. The relevant risk lies in engineering applications of reconnection and confinement rather than in anything demonstrated here; the treatment is at the level of topological bounds and carries no implementation detail. Governance of such applications belongs with the reconnection and fusion communities that would live with them.

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Tool and computational resource disclosure

Tools used. Claude (Anthropic), working under the author’s direction, wrote and ran the Python scripts deposited with this record, read their results from the run files, checked the citations listed in the literature pass, and drafted prose that the author edited. The audit that led to version 2 was also carried out with Claude, in a separate working session, and repeated every run before anything was changed. All numerical results reported here were produced by the deposited Python scripts, using numpy; Figure 5 was drawn with matplotlib. Typesetting used pandoc and wkhtmltopdf.

Responsibility. Responsibility for the correctness and adequacy of the arguments and results presented here, and for the completeness and accuracy of the citations, rests entirely with the named human author. No automated system is an author of this work.

Verification performed. Every run behind a number in this paper was repeated for version 2 and reproduced to every printed digit. Every number in the prose was filled from a run file, not retyped. Every citation was checked at the level the literature pass states for it. The final artifact was checked with `lint_deposit.py` before deposit.

Attribution limits. Moffatt (1990), Klotz and Thompson (2025), Maggioni, Alamri, Barengi and Ricca (2010), Kleckner and Irvine (2013), and Klenin and Langowski (2000) were checked at the level of the abstract only. Arnold (1974, 1986), Moffatt (1969) and Călugăreanu (1959, 1961) are cited through the papers read in full and were not re-fetched. Freedman and He’s Annals paper was read only on pages 220 to 229. The literature on numerically evaluated Gauss integrals is large and was not surveyed.

Computational resources. Each run takes seconds to a few minutes on one processor core.