Publishing in *Nature* Research Journals

Dr Bart Verberck, *Nature Research*

6 October 2017, Almaty, Kazakhstan

SPRINGER NATURE

1. Introduction to the *Nature* Research Journals

2. The editorial process at a *Nature* Research Journal

3. The role of scientific publishers

4. Conclusive remarks

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A WEEKLY ILLUSTRATED JOURNAL OF SCIENCE

"To the solid ground
Of Nature trusts the mind which builds for aye."—WORDSWORTH

THURSDAY, NOVEMBER 4, 1869

NATURE: APHORISMS BY GOETHE

NATURE! We are surrounded and embraced by her: powerless to separate ourselves from her, and powerless to penetrate beyond her.

Without asking, or warning, she snatches us up into her circling dance, and whirls us on until we are tired, and drop from her arms.

She is ever shaping new forms: what is, has never yet been; what has been, comes not again. Everything is new, and yet nought but the old.

We live in her midst and know her not. She is incessantly speaking to us, but betrays not her secret. We constantly act upon her, and yet have no power over her.

The one thing she seems to aim at is Individuality; yet she cares nothing for individuals. She is always building up and destroying; but her workshop is inaccessible.

Her life is in her children; but where is the mother? She is the only artist; working-up the most uniform material into utter opposites; arriving, without a trace of effort, at perfection, at the most exact precision, though always veiled under a certain softness.

Each of her works has an essence of its own; each of her phenomena a special characterisation: and yet their diversity is in unity.

She performs a play; we know not whether she sees it herself, and yet she acts for us, the lookers-on.

Incessant life, development, and movement are in her, but she advances not. She changes for ever and ever, and rests not a moment. Quietude is inconceivable to her, and she has laid her curse upon rest. She is firm. Her steps are measured, her exceptions rare, her laws unchangeable.

She has always thought and always thinks; though not as a man, but as Nature. She broods over an all-comprehending idea, which no searching can find out.

Mankind dwell in her and she in them. With all men she plays a game for love, and rejoices the more they win. With many, her moves are so hidden, that the game is over before they know it.

That which is most unnatural is still Nature; the stupidest philistinism has a touch of her genius. Whoso cannot see her everywhere, sees her nowhere rightly.

She loves herself, and her innumerable eyes and affections are fixed upon herself. She has divided herself that she may be her own delight. She causes an endless succession of new capacities for enjoyment to spring up, that her insatiable sympathy may be assuaged.

She rejoices in illusion. Whoso destroys it in himself and others, him she punishes with the sternest tyranny. Whoso follows her in faith, him she takes as a child to her bosom.

Her children are numberless. To none is she altogether miserly; but she has her favourites, on whom she squanders much, and for whom she makes great sacrifices. Over greatness she spreads her shield.

She tosses her creatures out of nothingness, and tells them not whence they came, nor whither they go. It is their business to run, she knows the road.

Her mechanism has few springs—but they never wear out, are always active and manifold.

The spectacle of Nature is always new, for she is always renewing the spectators. Life is her most exquisite invention; and death is her expert contrivance to get plenty of life.

She wraps man in darkness, and makes him for ever long for light. She creates him dependent upon the earth, dull and heavy; and yet is always shaking him until he attempts to soar above it.

B

Nature
A weekly illustrated journal of science
First issue, 4 November 1869

Nature’s hits …

- Discovery of X-rays
  (Röntgen, 1896)
- Wave nature of particles
  (Davisson & Germer, 1927)
- Discovery of the neutron
  (Chadwick, 1932)
- Structure of DNA
  (Watson & Crick, 1953)
- Discovery of pulsars
  (Hewish, Bell, Pilkington, Scott & Collins, 1968)
- Cloning of ‘Dolly’ the sheep
  (Wilmut *et al.*, 1997)
- …

… and misses

- Krebs cycle
  (rejected without review)
- Pavlov’s obituary
  (published while still alive)
- Schön case
  (fraud)
- …

nature research

SPRINGER NATURE

Nature Research Journals

Nature
life sciences
Research Journals

1983 1992 1994

...

Nature
physical sciences
Research Journals

2002 2005 2006 2007 2008 2009

...

Nature
'grand societal challenges'
Research Journals

2010 2015 2016

...

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Nature Research Journals

- Are **highly selective** (acceptance rates < 10%)
- Have a **high impact**
- Require **novelty** and **broad interest**
- Are staffed by **full-time professional editors** with a Ph.D.
- Have **no external editorial board** (of academics)
- Have a substantial **'front-half'** (Editorials, Commentaries, Research Highlights, Books & Arts, News & Views, …)
- Are **editorially independent** of each other (shared policies and designs but not submissions)
- **Overlap** somewhat in scope, but rejection at one journal does not rule out consideration at another

Why publish in a *Nature* Research Journal?

- **Exposure**
  - Your paper will be seen beyond your (specialist) field
- **Prominence**
  - Your paper will be one of a few — not lost in a sea of others in one issue
    Nature Physics publishes about 150 papers year^{-1}
  - Possibility of News & Views, cover, press release, ...
- **Care**
  - If we send your paper to referees we want to publish it
  - The editor handling your paper provides ‘personal assistance’
    A *Nature Physics* editor publishes about 25 papers year^{-1}

Care...

Local Thermometry of Neutral Modes on the Quantum Hall Edge

Vivek Venkatachalam[†1], Sean Hart[†1], Loren Pfeiffer[2], Ken West[2], Amir Yacoby[1]

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[2] Department of Electrical Engineering, Princeton University, Princeton, NJ, USA
[†]These authors contributed equally to this work

arXiv:1202.6681v1 [cond-mat.mes-hall] 29 Feb 2012

Summary: Quantum dots, used as local thermometers, detect upstream heat transport in a $\nu = 2/3$ fractional quantum Hall edge state, even when the state is carrying no net charge.

Abstract

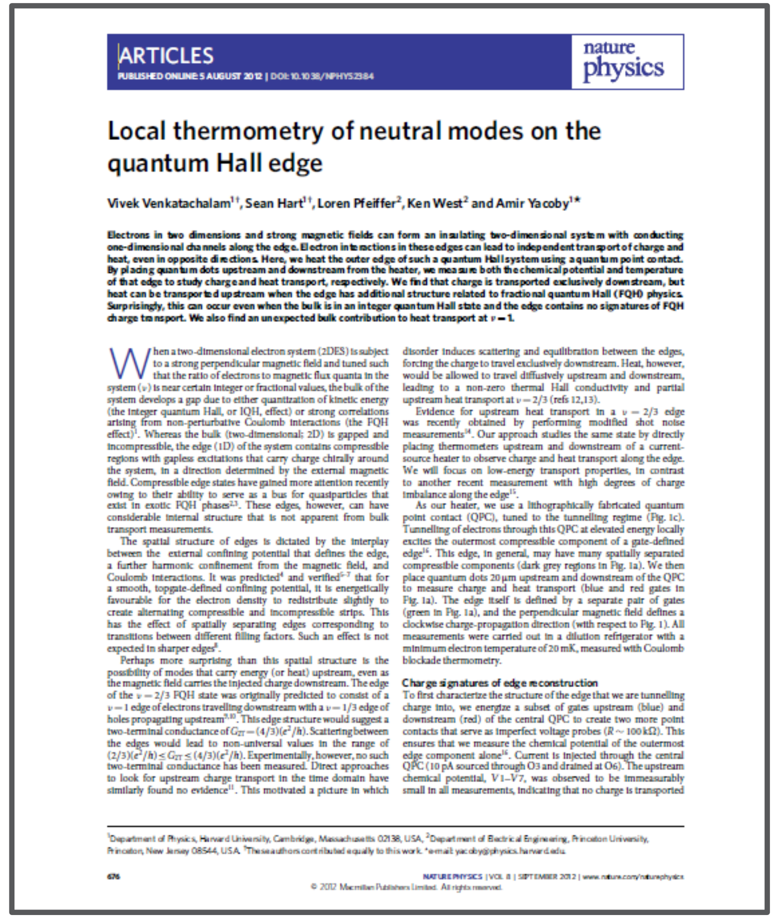
A system of electrons in two dimensions and strong magnetic fields can be tuned to create a gapped 2D system with one dimensional channels along the edge. Interactions among these edge modes can lead to independent transport of charge and heat, even in opposite directions. Measuring the chirality and transport properties of these charge and heat modes can reveal otherwise hidden structure in the edge. Here, we heat the outer edge of such a quantum Hall system using a quantum point contact. By placing quantum dots upstream and downstream along the edge of the heater, we can measure both the chemical potential and temperature of that edge to study charge and heat transport, respectively. We find that charge is transported exclusively downstream, but heat can be transported upstream when the edge has additional structure related to fractional quantum Hall physics.

When a two-dimensional electron system (2DES) is subject to a strong perpendicular magnetic field and tuned such that the ratio of electrons to magnetic flux quanta in the system (ν) is near certain integer or fractional values, the bulk of the system develops a gap due to either quantization of kinetic energy (the integer quantum Hall, or IQH, effect) or strong correlations arising from non-perturbative Coulomb interactions (the fractional quantum Hall, or FQH, effect) [1]. While the bulk (2D) is gapped and incompressible, the edge (1D) of the system contains compressible regions with gapless excitations that carry charge chirally around the system, in a direction determined by the external magnetic field. Compressible edge states have gained more attention recently owing to their ability to serve as a bus for quasiparticles that exist in exotic FQH phases[2, 3]. These edges, however, can have considerable internal structure that is not apparent from bulk transport measurements.

The spatial structure of edges is dictated by the interplay between the external confining potential which defines the edge, an additional harmonic confinement from the magnetic field, and Coulomb interactions. It was predicted [4] and verified [5, 6, 7] that for a smooth, topgate-defined confining potential, it is energetically favorable for the electron density to redistribute slightly to create alternating compressible and incompressible strips. This has the effect of spatially separating edges corresponding to different filling factors. Such an effect is not present in sharper edges [8].

Perhaps more surprising than this spatial structure is the possibility of modes that carry energy (or heat) upstream, even as the magnetic field carries the injected charge downstream. The edge of the $\nu = 2/3$ FQH state was originally predicted to consist of a $\nu = 1$ edge of electrons going downstream with a $\nu = 1/3$ edge of holes going upstream [9, 10]. However, this edge structure would suggest a two-terminal conductance of $G_{2T} = \frac{4}{3}\frac{e^2}{h}$. Scattering between the edges would lead to non-universal values in the range of $\frac{2}{3}\frac{e^2}{h} \leq G_{2T} \leq \frac{4}{3}\frac{e^2}{h}$. Experimentally, however, no such two terminal conductance has been measured. Direct approaches to look for upstream charge transport in the time domain have similarly turned up no evidence [11]. This motivated a picture in which disorder induces scattering and equilibration between the edges, forcing the charge to travel exclusively downstream. Heat, however,

1



ARTICLES
PUBLISHED ONLINE: 5 AUGUST 2012 | DOI: 10.1038/NPHYS2384

nature physics

Local thermometry of neutral modes on the quantum Hall edge

Vivek Venkatachalam[1†], Sean Hart[1†], Loren Pfeiffer[2], Ken West[2] and Amir Yacoby[1*]

Electrons in two dimensions and strong magnetic fields can form an insulating two-dimensional system with conducting one-dimensional channels along the edge. Electron interactions in these edges can lead to independent transport of charge and heat, even in opposite directions. Here, we heat the outer edge of such a quantum Hall system using a quantum point contact. By placing quantum dots upstream and downstream from the heater, we measure both the chemical potential and temperature of that edge to study charge and heat transport, respectively. We find that charge is transported exclusively downstream, but heat can be transported upstream when the edge has additional structure related to fractional quantum Hall (FQH) physics. Surprisingly, this can occur even when the bulk is in an integer quantum Hall state and the edge contains no signatures of FQH charge transport. We also find an unexpected bulk contribution to heat transport at $\nu = 1$.

When a two-dimensional electron system (2DES) is subject to a strong perpendicular magnetic field and tuned such that the ratio of electrons to magnetic flux quanta in the system (ν) is near certain integer or fractional values, the bulk of the system develops a gap due to either quantization of kinetic energy (the integer quantum Hall, or IQH, effect) or strong correlations arising from non-perturbative Coulomb interactions (the FQH effect)[1]. Whereas the bulk (two-dimensional; 2D) is gapped and incompressible, the edge (1D) of the system contains compressible regions with gapless excitations that carry charge chirally around the system, in a direction determined by the external magnetic field. Compressible edge states have gained more attention recently owing to their ability to serve as a bus for quasiparticles that exist in exotic FQH phases[2,3]. These edges, however, can have considerable internal structure that is not apparent from bulk transport measurements.

The spatial structure of edges is dictated by the interplay between the external confining potential that defines the edge, a further harmonic confinement from the magnetic field, and Coulomb interactions. It was predicted[4] and verified[5–7] that for a smooth, topgate-defined confining potential, it is energetically favourable for the electron density to redistribute slightly to create alternating compressible and incompressible strips. This has the effect of spatially separating edges corresponding to transitions between different filling factors. Such an effect is not expected in sharper edges[8].

Perhaps more surprising than this spatial structure is the possibility of modes that carry energy (or heat) upstream, even as the magnetic field carries the injected charge downstream. The edge of the $\nu = 2/3$ FQH state was originally predicted to consist of a $\nu = 1$ edge of electrons travelling downstream with a $\nu = 1/3$ edge of holes propagating upstream[9,10]. This edge structure would suggest a two-terminal conductance of $G_{2T} = (4/3)(e^2/h)$. Scattering between the edges would lead to non-universal values in the range of $(2/3)(e^2/h) \leq G_{2T} \leq (4/3)(e^2/h)$. Experimentally, however, no such two-terminal conductance has been measured. Direct approaches to look for upstream charge transport in the time domain have similarly found no evidence[11]. This motivated a picture in which disorder induces scattering and equilibration between the edges, forcing the charge to travel exclusively downstream. Heat, however, would be allowed to travel diffusively upstream and downstream, leading to a non-zero thermal Hall conductivity and partial upstream heat transport at $\nu = 2/3$ (refs 12,13).

Evidence for upstream heat transport in a $\nu = 2/3$ edge was recently obtained by performing modified shot noise measurements[14]. Our approach studies the same state by directly placing thermometers upstream and downstream of a current-source heater to observe charge and heat transport along the edge. We will focus on low-energy transport properties, in contrast to another recent measurement with high degrees of charge imbalance along the edge[15].

As our heater, we use a lithographically fabricated quantum point contact (QPC), tuned to the tunnelling regime (Fig. 1c). Tunnelling of electrons through this QPC at elevated energy locally excites the outermost compressible component of a gate-defined edge[16]. This edge, in general, may have many spatially separated compressible components (dark grey regions in Fig. 1a). We then place quantum dots 20 µm upstream and downstream of the QPC to measure charge and heat transport (blue and red gates in Fig. 1a). The edge itself is defined by a separate pair of gates (green in Fig. 1a), and the perpendicular magnetic field defines a clockwise charge-propagation direction (with respect to Fig. 1). All measurements were carried out in a dilution refrigerator with a minimum electron temperature of 20 mK, measured with Coulomb blockade thermometry.

Charge signatures of edge reconstruction

To first characterize the structure of the edge that we are tunnelling charge into, we energize a subset of gates upstream (blue) and downstream (red) of the central QPC to create two more point contacts that serve as imperfect voltage probes ($R \sim 100$ kΩ). This ensures that we measure the chemical potential of the outermost edge component alone[16]. Current is injected through the central QPC (10 pA sourced through O3 and drained at O6). The upstream chemical potential, V1–V7, was observed to be immeasurably small in all measurements, indicating that no charge is transported

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A lot of work done by a lot of people!

SPRINGER NATURE

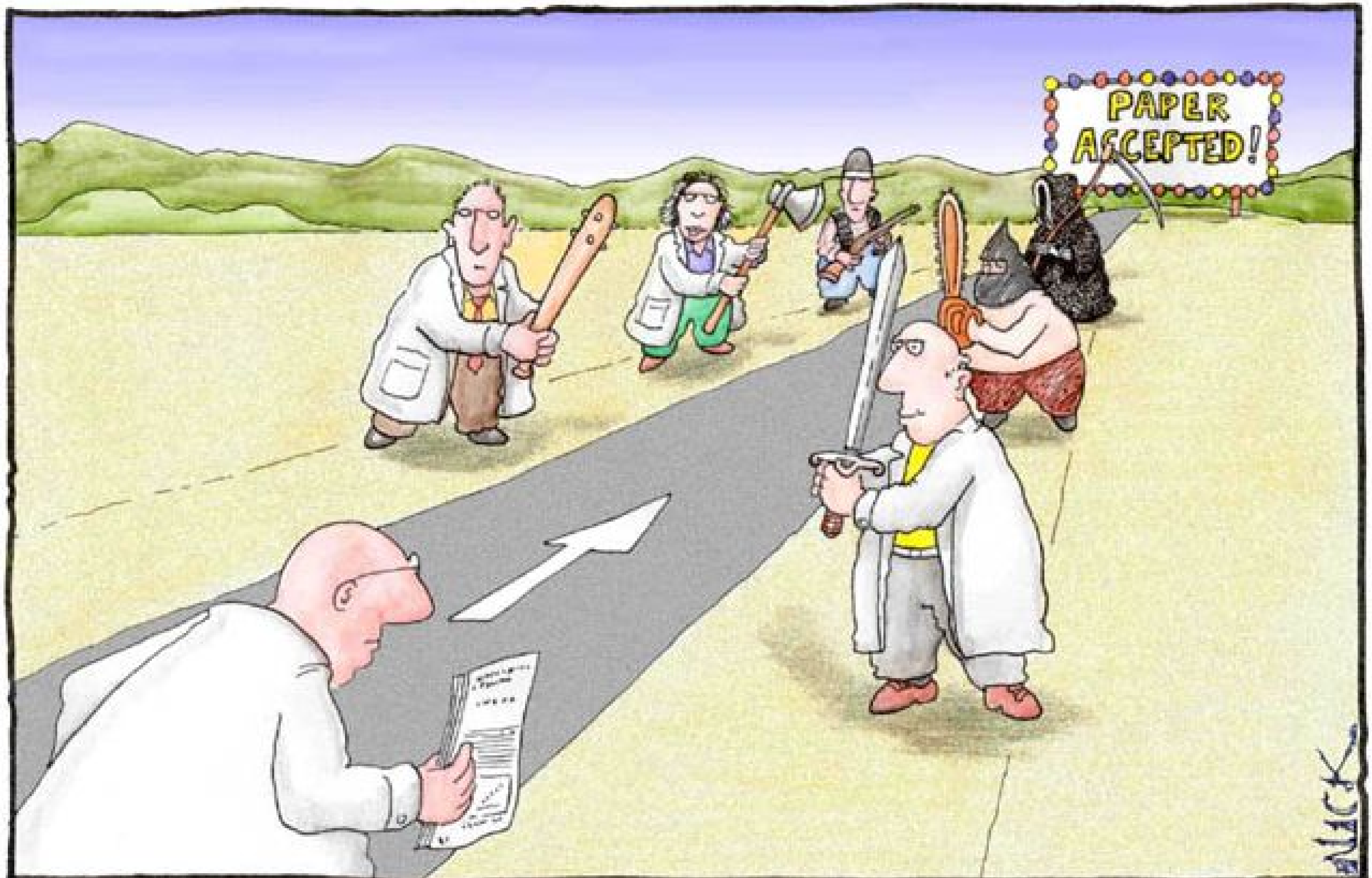
1. Introduction to the *Nature* Research Journals

2. The editorial process at a *Nature* Research Journal

3. The role of scientific publishers

4. Conclusive remarks

Some common misconceptions…



Some common misconceptions…

“You have to know one of the editors.”

“The editorial process is a black box.”

“It’s a lottery.”

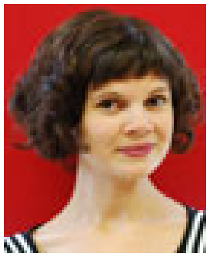
“The papers in Nature Physics are over-hyped.”

“Theory-only papers don’t stand a chance.”

Here’s how it really works…

The *Nature Physics* editors

Dr Andrea Taroni
Chief Editor



Dr Abigail Klopper
Senior Editor

Dr Bart Verberck
Senior Editor

Dr Iulia Georgescu
Senior Editor

Dr Luke Fleet
Senior Editor

My background

- 2005: **PhD** in Physics at U. Antwerp
(structural and electronic properties of fullerene crystals)

- 2005 – 2013: **Postdocs** at U. Antwerp, FZ. Jülich, U. Paris-Sud and U. Würzburg
(structural and electronic properties of carbon nanostructures; theory & simulations, …)

- 2013: **Associate/Senior Editor** at *Nature Physics*
(handling manuscripts on solid-state physics (structural, electronic and thermal properties), soft matter, plasma physics, hydrodynamics, nuclear physics, …)

- 2017: **Regional Executive Editor – Berlin**
(*Nature Research* Berlin office, outreach in Germany & beyond)

What do the editors do?

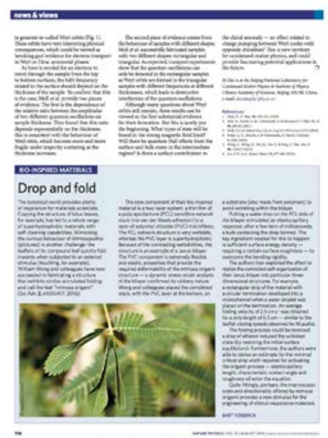
- **Select** the top papers submitted to the journal
  - Read the cover letter, manuscript and supplementary information
  - Do a literature search and consult additional sources
  - Discuss the paper with other editors; sometimes seek informal advice from an expert
  - Reach a decision whether to send the paper out for formal review or not
- **Handle** the selected papers (referees, reports, decisions)

(What else do the editors do?)

- **Liaise** with the scientific community (attending conferences, visiting laboratories, giving presentations, being in panels, co-organizing events, …)
- **Write** for the journal (Editorials, Books & Arts, Research Highlights, News & Views, …)
- **Commission** content for the journal (Commentaries, Reviews, Columns, …)

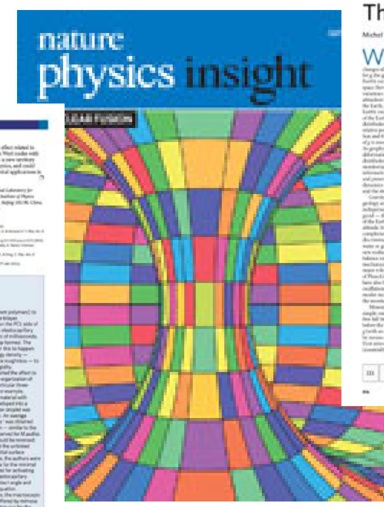

books & arts

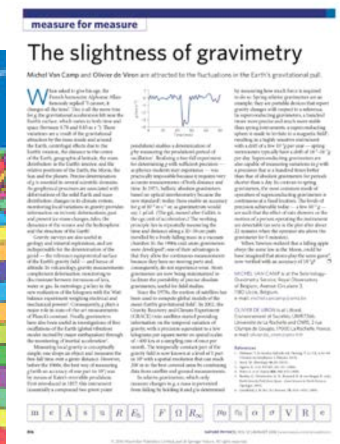
Cosmic technoculture


news & views

BIO-INSPIRED MATERIALS

Drop and fold




measure for measure

The slightness of gravimetry

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What are the editors looking for?

- There is **no definitive answer** to this question; there is **no secret formula**...
- The goal is that every paper published [in *Nature Physics*] provokes a response [from any physicist] of the type "**Wow!** I didn't expect that!" or "**Wow!** That's clever/useful!"
- There are some **criteria** ('necessary ingredients')
  - Significant advance in our understanding
  - Broad relevance beyond the immediate field of research
  - Comprehensible story
- **Referees** judge technical correctness, novelty, broader relevance and accessibility

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Preparing a submission — what to keep in mind?

- Publishing starts with **new results**… Think well ahead and self-reflect (*"Where does my work fit into the field?"*)
- High-impact journals don't consider work representing an **incremental step forward** (no matter how hot the topic!)
- Avoid salami-slicing — an **all-in paper** has more chance of being published quickly than one based on partial results!
- Don't confuse **scientific interest** with 'newsworthiness'
- Read a journal's **guide to authors** and comply with its **policies**
- Don't be shy to approach high-impact journals with your **best work**!
- **Results** should speak for themselves — but you have to help the reader to get the message

Intermezzo

Some advice on writing titles and abstracts (and papers)

The structure of a paper

- **Title**: invites the reader in (*"What is the paper about?"*)
- **Abstract**: provides context to the reader (*"Why should someone care?"*)
- **Main text**: elaboration of the central idea
  - Tell a story! The clearer and simpler, the better. Make good use of figures, tables, Methods and Supplementary Information sections to enhance the story-telling
  - Consider the **'ABC'** of scientific writing...
    Be **accurate** ("atto-second" not "ultra-fast", nano?)
    Be **brief** (to the point, no redundancies and repetitions)
    Be **clear** (break up sentences, use active voice)

Get the title right

~~*"Study of the temperature dependence of Y"*~~

- The title should **attract** the reader (and the editors/referees!)
- Put in one or two carefully selected **keywords** (web searches!)
- Consider the **'DEF'** of scientific title writing…
  Be **declarative** (*"A increases Z"* not *"The effect of A on Z"*)
  Be **engaging** (avoid acronyms, jargon and complex nouns)
  Provide **focus** (only one key message)
- A title should be **understandable** the first time it is read
- **Balance** broad appeal with sufficient detail

"Temperature hysteresis of Y due to B"

Get the abstract right

- **Reader**: needs to decide whether the paper is worth reading
  Author: wants his/her work to be picked up and disseminated
- The abstract is a **mini-version** of the paper. It should provide just enough context and detail so that the reader understands **what** has been done, **why** and **how**
- Potential **referees** will decide to review based on the abstract
- Consider the **'*Nature* formula'**…
  1. One or two general statements setting the **context**
  2. Statement of the **'gap'** in our knowledge
  3. Headline conclusion of the findings (***"Here, we show …"***)
  4. Brief summary of **approach**, **key results** and **conclusions**
  5. Short description of **advance** and **impact**

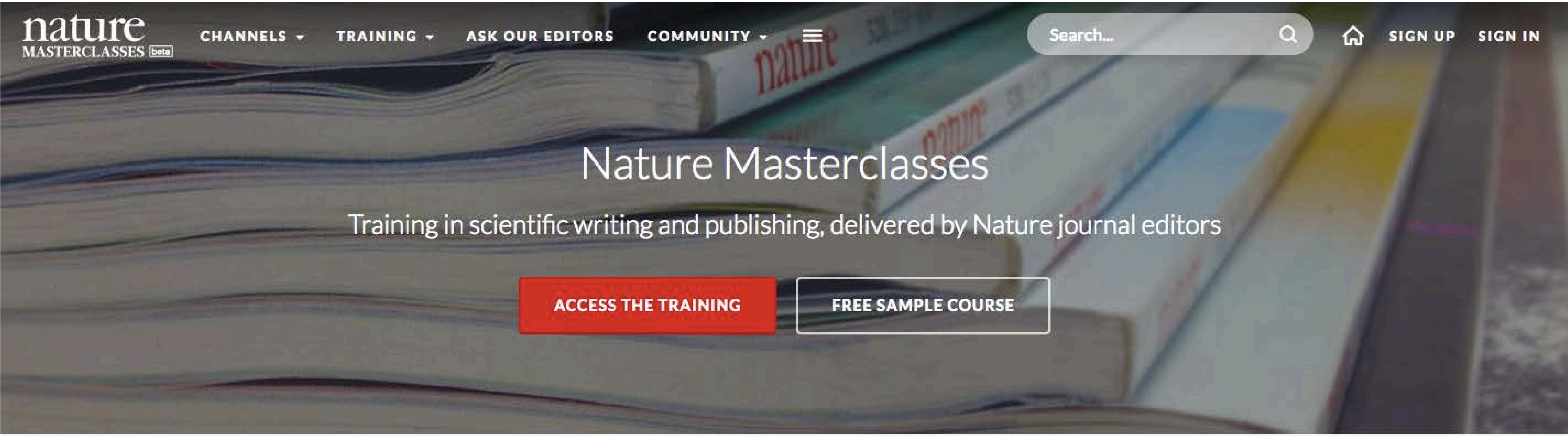
Get the abstract right — the ‘*Nature* formula’…

1. context	Sources such as [s] are important because [explanation]. Crucial to our understanding of [s] is a measurement of [p], because this has the potential to reveal [q].
2. ‘gap’	In the past, this has been very difficult to accomplish, because [reason].
3. *“Here, we show …”*	Here, we show that high-precision measurements of [p] can now be achieved by means of a combination of [m] and [n].
4. approach key results conclusions	We applied [methodological information on m and n] to a system consisting of [c] and find that [insights about q], demonstrating that [conclusion about s].
5. advance impact	Our approach involving the use of [m] and [n] is also applicable to [r], which will lead to further insights concerning [s] and their development.

Further advice for authors with Russian as native language

- Don’t be shy to use **active voice**
  - «Было показанно, что …» (“It has been shown that …”): Кем?
    We show that … / Urgant *et al.* [1] have shown that …
- Write immediately in **English** (yourself)
  - Your original writing will be closest to what you want to say
  - A translator is not as close to your work as you are and may not be very familiar with your field of research
  - You’ll get better every time
  - An editor’s job is to assess the merit of a paper based on its content, not its language

masterclasses.nature.com



1. *Nature* Research Journals

2. The editorial process at a *Nature* Research Journal (cont.)

Preparing a submission — practicalities

- At the initial submission stage format is not really important. Spend your time on the **clarity** and **accessibility** of your paper
- Prepare a **cover letter** — a good cover letter is **very useful** for editors!
  - Explain (informally) the appeal of your work (but don't oversell it)
  - Referee suggestions are welcome (but don't suggest your former supervisor or students or (recent) collaborators — editors check!)
  - Referee exclusion requests are usually honoured, as long as they are reasonable
  - Identify all related papers in press or submitted elsewhere

Welcome to the **Nature Physics** online manuscript submission and tracking system. Please be sure that your browser is set to accept cookies, as our tracking system requires them for proper operation.

If you are a first-time user please read our instructions for authors or instructions for referees before logging in. Please note that passwords are case sensitive.

If you experience any problems, please contact the NPG Applications Helpdesk.

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Compliance with open access mandates and self-archiving
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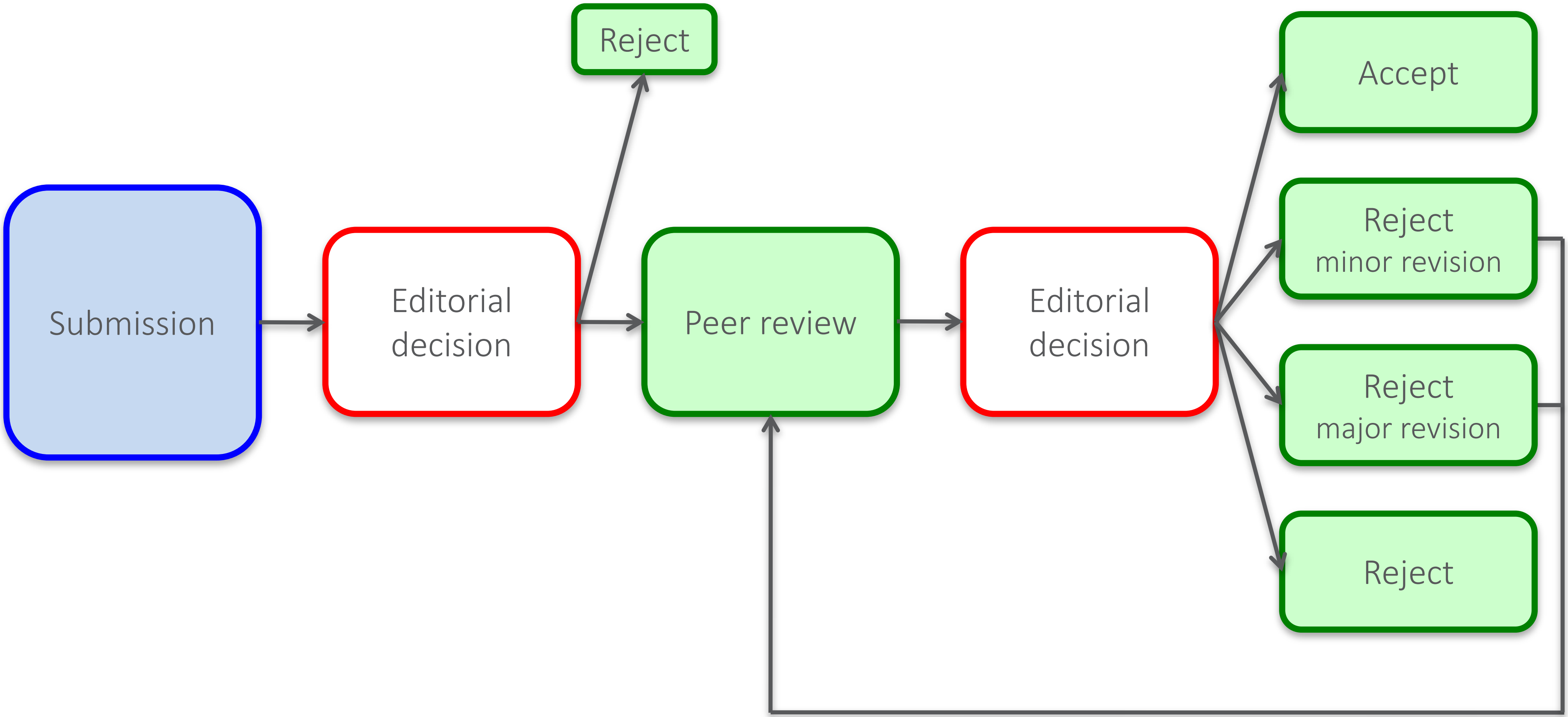
The editorial process at a *Nature* Research Journal

- **First decision** (reject or send out for peer review) within one week (as far as possible)
- An editor **reads** the manuscript; often **discusses** manuscripts with other editors; sometimes informally consults an **expert**
- Typical **editorial checks**:
  - What is the novelty of the claims?
  - How well do the data support the claims?
  - Is the work of interest beyond the specialist community?
- Decision is to a great extent based on **editor expertise**
  A *Nature Physics* editor reads about 400 papers year^{-1}
- When in **doubt**, send it out!

The editorial process at a *Nature* Research Journal



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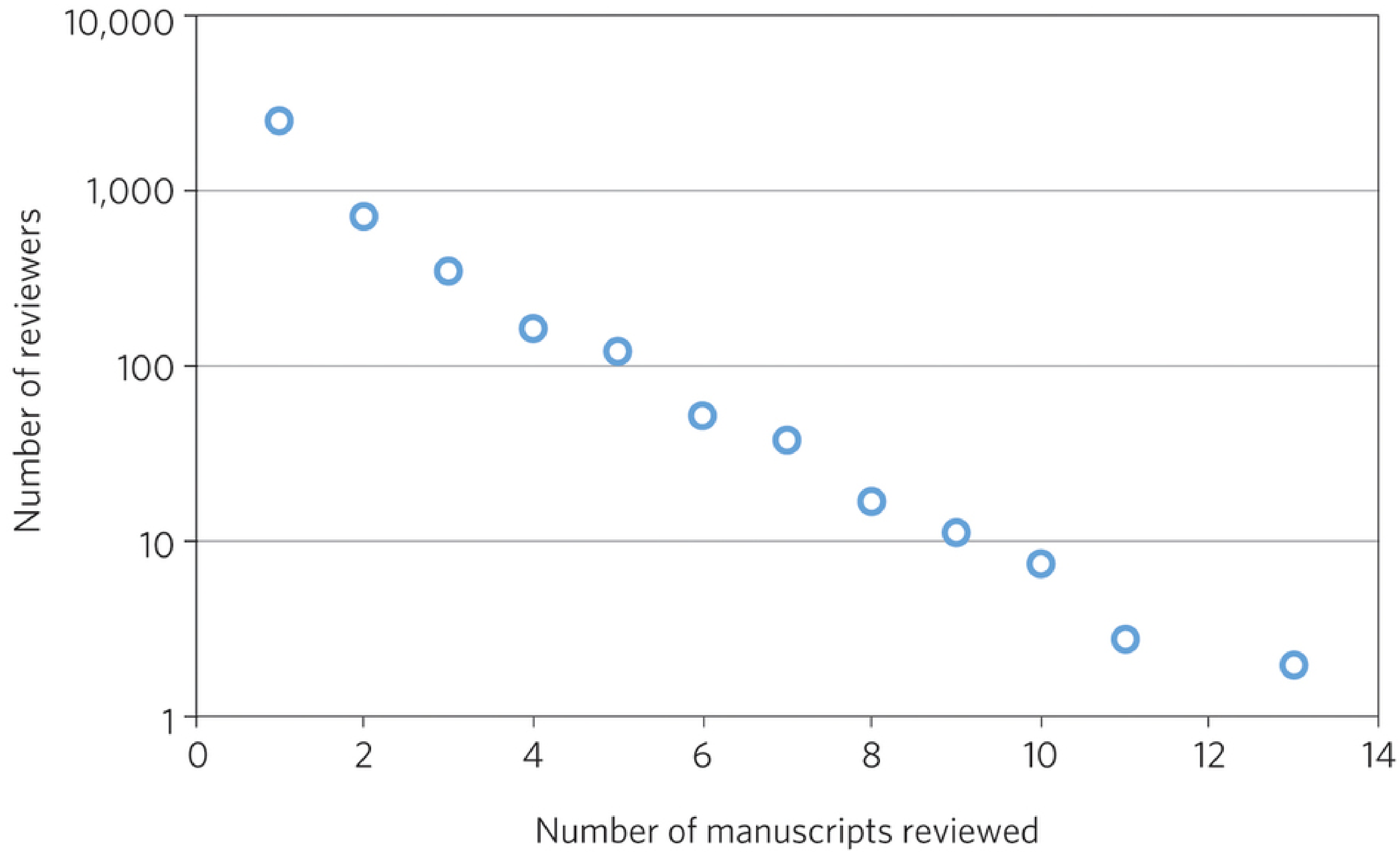
Referees at a *Nature* Research Journal

- We **hand-pick** referees on a paper-by-paper basis
- We aim for **2 – 4 referees** per paper
- We try to use a referee **not more than once or twice a year** — no clique-forming (we also appreciate that scientists are busy!)
- Continuously **expanding pool** of referees
- Referee **qualities**:
  - Technical expertise and experience in the field
  - Broad overview
  - Reliability (2-week turnover time)
- Referee **reports** should be fair, clear, detailed and constructive

Referees at *Nature Physics* (March 2005 – September 2015)



SPRINGER NATURE

Decisions after review

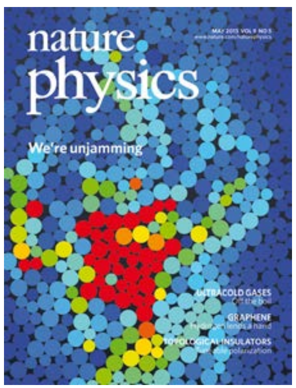
- Editors make a decision (Accept, Reject – minor revision, Reject – major revision, Reject) based on the **referee reports**
  - We ask referees to comment on the merits of a paper and its technical correctness — not whether they think the paper should be published in our journal or not
  - We don't count votes!
- Revisions must make **substantial progress** towards justifying publication
- In borderline cases we try to **avoid multiple rounds of review** — almost good enough is not good enough…
- We can be **patient** and wait for extra work to be completed
- Editors take **ultimate responsibility** for decisions

Resubmitting

- If invited to resubmit, only do so after you have addressed **all of the referees' comments**
- If **extra work** was requested, don't try to argue your way out of it!
- Be **professional** and **respectful** — our referees are your peers and colleagues
- If a referee has **misunderstood** or failed to appreciate the significance of your work, that may be not his/her fault alone

Manuscript transfer

- If **rejected** by *Nature Physics*, you can transfer your manuscript to another *Nature* Research Journal, *Nature Communications* or any other Springer Nature journal via a link provided
- You can choose to opt out of **inter-journal editorial consultations**
- *Nature* Research Journals and *Nature Communications* are **editorially independent**



nature COMMUNICATIONS

Unhappy about an editorial decision?

- If you think editors and/or referees have misunderstood (the importance of) your work, **we want to know** about it. We do make mistakes!
- We will only alter our decision if we are **convinced** that there has indeed been a misunderstanding
  - 2 out of 3 referees were positive? Not sufficient justification for an appeal
- We take appeals **very seriously** but they have a lower priority than new submissions — please be patient

How to appeal an editorial decision

- If possible, present **additional data** to make your point
- If applicable, **point out factual errors** in the decision progress — but argue scientifically and collegially!
- Don’t just demand reconsideration — **make a case**!
- If your paper was refereed, write a clear, point-by-point **rebuttal**
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FLUID DYNAMICS

Lord Kelvin's vortex rings

Linking two smoke rings or tying a single ring into a knot is no easy feat. Such topological vortices are now created in water with the aid of specially printed hydrofoils.

Daniel P. Lathrop and Barbara Brawn-Cinani

Turbulence and vortices are everyday occurrences we have all experienced — from gusty winds on a street corner to distinctive sudden shaking during air travel. Vortex rings are a related phenomenon that are also familiar: visible in the clouds under a meteorological microburst and in a smoker's exhale (although such smoke rings are more healthily created using a simple cannon comprising only a drum with a circular hole in its end). Such vortical structures also play a fundamental role in fluid dynamics and have been subjects of intense study since the days of Lord Kelvin. However, laboratory studies so far have been limited to studying isolated or colliding rings. Dustin Kleckner and William Irvine have now gone beyond such simple systems by creating knotted and linked vortices, as they describe in *Nature Physics*[1].

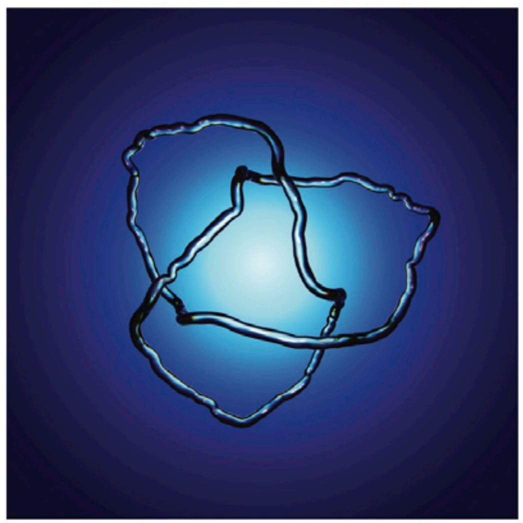
A vortex ring is simply described as a tornado that has been bent into a closed loop. Whereas this example occurs in air, vortex rings also exist in water, plasmas and quantum fluids (superfluids)[2]. Ideal vortices, for which vorticity occurs only in the core, are a convenient tool for analysing flows with limited viscous effects. Notably, they dominate the dynamics of superfluid helium flows and quantum-fluid Bose–Einstein condensates. For line-like vortex cores, topology describes the key properties of connectedness and continuity under deformations like stretching or twisting. As such, research into topological fluid dynamics[3,4] aims to better understand turbulence in fluids and plasmas.

Kleckner and Irvine have now reached beyond simple smoke rings and ideal vortices to produce more topologically complicated linked and knotted rings. The physics of linked vortices is much richer that that of single vortices: they will, for example, influence each other, generally making particle paths helical. The results also address some outstanding issues about topology change in vortex systems. Can vortices unknot, and if so how? Does unknotting, which is a change of topology, cause significant stress on the system? The initial answers here are: yes, they do unknot, and yes, this does cause a stressful wrinkling of the vortices.

But how did the team create these complex structures, a feat that has evaded us for a century? They realized that a three-dimensional printer could form airfoils capable of launching knotted vortices; a brilliant linking of newly available technology with outstanding research issues. As this is an early use of 3D technology in fluid mechanics, we might expect other applications and science to emerge from this marriage. Imagine 3D printed and automated fish or dragonflies for future studies!

These vortex observations are also relevant to other research communities: topology and topological change are critical in a broad range of physical systems. Line-like topological foci appear in a surprisingly large range of phenomena: type-II superconductors, superfluid vortices, dislocations in crystal plasticity, and magnetic helicity[5] and reconnection in plasmas[6] — as occurs in the solar corona and the Earth's magnetosphere. Examining the excellent imagery of solar coronal dynamics, one can easily imagine that the topology of the magnetized plasma plays an important role. Many current quantum-field-theory candidates also have topological solutions; cosmic strings are one example.

The work of Lord Kelvin informs much of our current knowledge on thermodynamics, but he also contributed important early ideas about electrodynamics and the dynamics of vortices. He would have been keenly interested in the current work. In fact, Kelvin waves are now understood to be the main disturbances on a long, straight vortex. These transverse helical waves are clearly seen in tornadoes, or



An example of a trefoil knotted vortex ring. Image provided by Dustin Kleckner and William T. M. Irvine

"First fluid knots created in the lab"
— New Scientist

"Physicists twist water into knots"
— Nature News

"Physicists create vortex knot – akin to 'tying a smoke ring'"
— Wired

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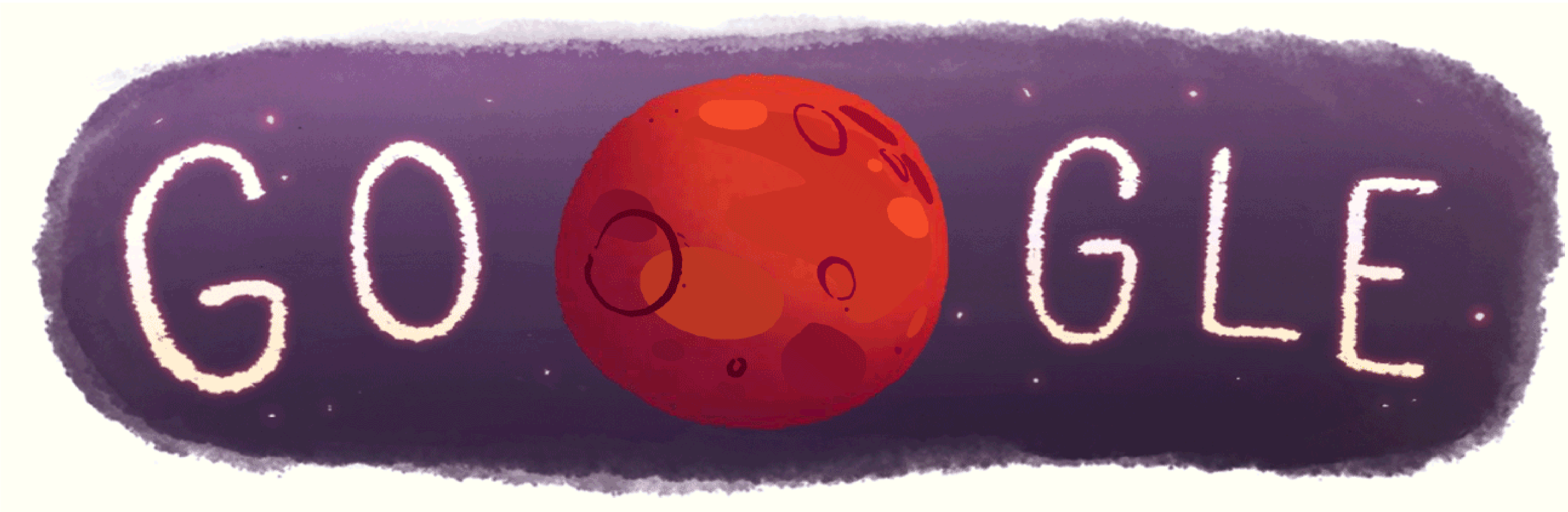

"Spectral evidence for hydrated salts in recurring slope lineae on Mars"

Nature Geoscience **8**, 829–832 (2015) doi:10.1038/ngeo2546

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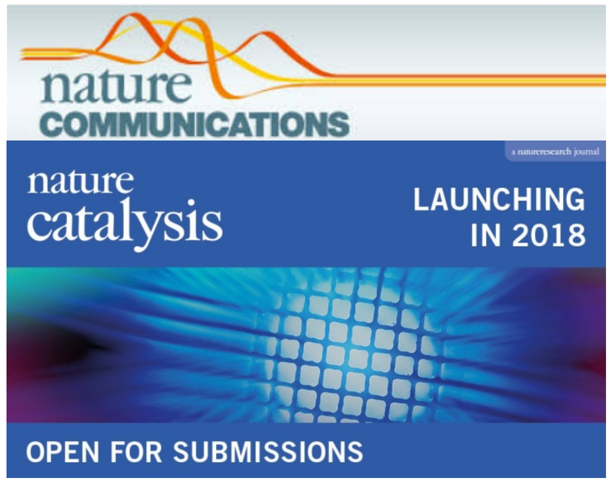

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