
George Keith Batchelor
(1920-2000)
A personal reminiscence
Keith Moffatt
Trinity College, Cambridge

George Batchelor in his very small office in the Old Cavendish Laboratory1956, just after publication of the first issue of the *Journal of Fluid Mechanics*.

This was where, in 1958, I asked George if he would take me on as a research student in turbulence, a subject in which he was an acknowledged world leader.

I was lucky that he said YES.

Zakopane, Poland, September 1963, for the 3rd Biennial Symposium in Fluid Mechanics George Batchelor with his daughters Adrienne, Bryony, Clare, and his wife Wilma

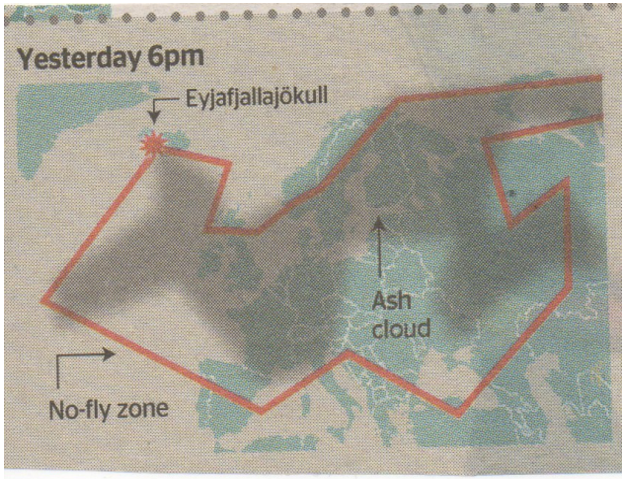
George had offered to take me by car (an old Ford Zodiak) to Zakopane with his young family, and I gladly accepted this invitation! We travelled via Holland, Germany and Czechoslovakia to Poland — quite an adventure in those days!

Here is the situation considered by GKB at the Zakopane meeting: a point source of pollutant that is convected downstream in the constant stress layer of a turbulent air flow

Batchelor (1964) Diffusion from sources in a turbulent boundary layer, Archivum Mech. Stosowanej, 3(16), 661-670

Eyjafjallajökull, April 17, 2010

Statistical properties of a marked fluid particle depend only on u^* and on time t since release. Mean concentration downstream at ground level decreases like x^{-2} for a continuous point source.



Times 19 April 2010 – Kangaroo cloud?

Kangaroo cloud !

From my own paper at the Zakopane meeting, 1963

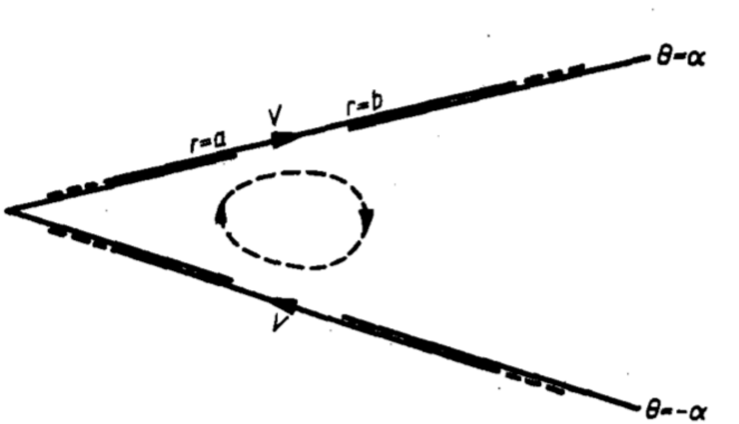


FIG. 1. Flow in a corner induced by the motion of two sleeves in the region $a < r < b$ of the walls $\theta = \pm \alpha$.

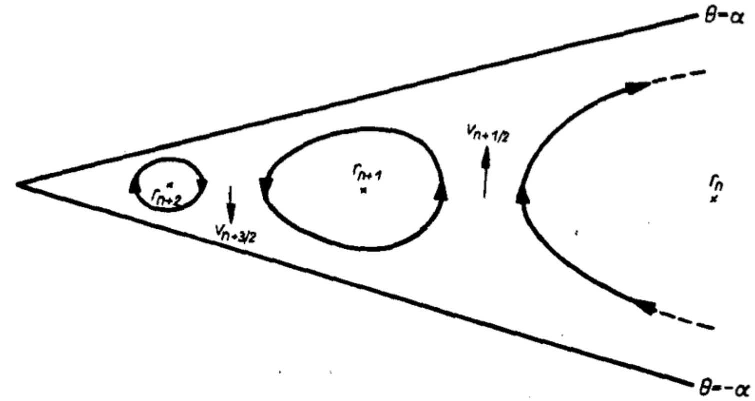
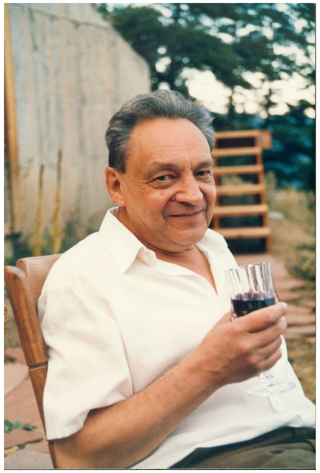


FIG. 2. The sequence of corner eddies when $2\alpha = 30°$; Geometric scale factor $\varrho_1 = 2.1$. Dynamical scale factor $\omega_1 = 403$.

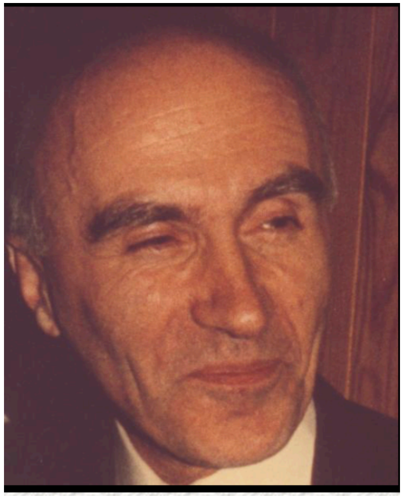
At the same meeting, my own lecture was on corner flow, and the sequence of eddies that appear near the corner due to any remote stirring mechanism. I remember that when I rather hesitantly took this result to Batchelor, I expected him to say “you must have made a mistake, go away and check the algebra”; but, no, he said "that looks quite possible, you may be right", and encouraged me to write the paper. This was typical of George, always encouraging to students and much younger colleagues.

Batchelor had strong links with Poland, through Ryszard Herczynski (visitor to DAMTP, Cambridge, 1960/61) and Wladek Fiszdon. The biennial meetings in Poland, organised by Fiszdon from 1959 till 1989, were instrumental in maintaining contact between East and West during the Cold War.



Richard Herczynski
(in Boulder 1988)
He first visited
Cambridge 1960/61

GKB scheming with Wladek Fiszdon
and Richard Herczynski, Warsaw 1979



Wladek Fiszdon
Promoter of Polish
Biennial Fluid Mechanics
Symposia 1959 - 1989

Herczynski was imprisoned for a period during the Solidarność years (1980s), and George was very supportive throughout this period.

The Marseille 1961 Watershed

Watershed: a crucial point or dividing line between two phases, conditions, etc

Colloque Internationale du CNRS to mark the opening of the former Institut Statistique de la Turbulence [Favre, Gaviglio, Dumas, . . .]

Excursion to the Roman ruins at Arles

Batchelor chats with the legendary Theodore von Karman

Conference dinner

Lasting impact: A 50th Anniversary Colloquium was held in 2011

Farge, Moffatt & Schneider 2013, *Fundamental Problems of Turbulence 50 years after the Marseille 1961 Conference,* CIRM, Marseille, September 2011. J. Turbulence, 14

Batchelor's concluding remarks on Homogeneous Turbulence at the Marseille (1961) Colloquium

I highlight here just three of his statements:

- *Formal mathematical investigations have produced remarkably little of value; successful theoretical work more often takes the form of simple deductions from an assumed plausible physical model of a limited aspect of the flow.*

He might still say the same today! (*cf.* yesterday's lecture by Bérengère Dubrulle)

- *The universal similarity theory of the small-scale components of the motion stand out . . . as a valuable contribution, of which an increasing number of applications is being made, especially in problems involving convection and diffusion of scalar and vector properties of the fluid.*

Kolmogorov had presented his "*refinement of previous hypotheses*" (in French) the previous day.

- *There is a need . . . for measurement of the mean values of third and fourth powers of velocity derivatives at very high Reynolds numbers; these might throw light on the obscure and interesting question of the way in which the energy of the small-scale components is distributed over the fluid.*

Here, Batchelor anticipated the need to understand intermittency, a focus of much turbulence research in subsequent decades.

Batchelor's first work for CSIRO, Australia
Dated 1942

SECRET

M. Batchelor · 1942

SECRET

Aerodynamics Note No. 16. (7)

NOTE ON THE AERIAL FLIGHT OF A TORPEDO BOMB

by G.K. Batchelor, M.Sc.

SUMMARY

A pair of wings and a tailplane have been developed for a bomb so that when released at a height of about 70 feet above th water it will strike the water at some positive angle of incidence It is assumed from previous full scale tests that the bomb then bounces off the water due to the hydrodynamic lift created by the wings.

1. Introduction

It was postulated that if a bomb could be made to bounce off the water and maintain its course, when dropped from a low height, it would provide a simple and accurate method of bombing a ship. Aerodynamic and hydrodynamic accessories could be fitted to the outside of the aerial bomb to achieve this effect without disturbing the normal manufacturing process.

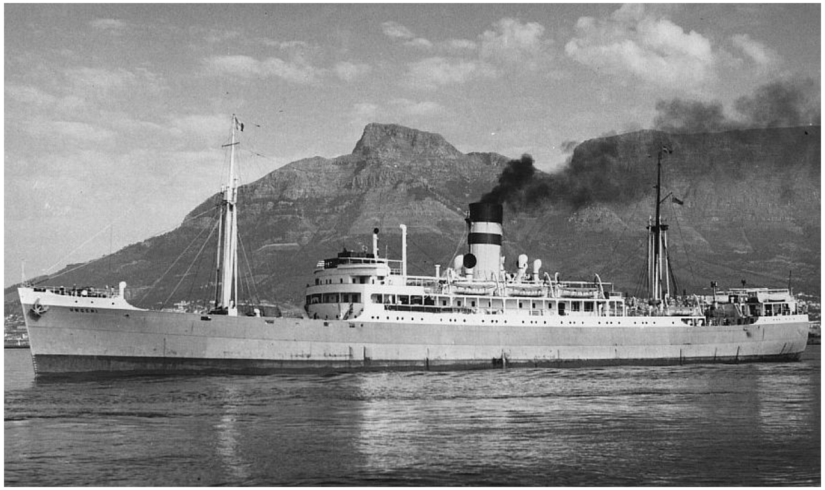
Observation has previously shown that an ordinary torped may bounce if it strikes the water at certain attitudes. This indicates that if wings of fairly small area are fitted to the bomb, the hydrodynamic lift will be sufficient to cause it to bounce if it strikes at the correct water incidence. Since, on striking the water at any positive incidence, the tail of the bomb strikes firs producing a large nose-downward pitching moment tending to decreas the incidence, the correct striking incidence is a matter of doubt and is probably not critical. It seems likely, however, that a

The Dambusters

Operation Chastise was an attack on German dams carried out on **16–17 May 1943** by Royal Air Force No. 617 Squadron subsequently known as the "Dambusters", using a specially developed "bouncing bomb" invented and developed by Barnes Wallis. The Möhne and Edersee Dams were breached, causing catastrophic flooding of the Ruhr valley and of villages in the Eder valley, while the Sorpe dam sustained only minor damage.

A little background: GKB was born in Melbourne, Australia 1920; schooled in Melbourne, and won a scholarship to Melbourne University, graduating in maths and physics 1939, just as World War II broke out.

While researching in Aerodynamics with CSIR throughout the war, he recognised turbulence as a key problem, and studied the papers of G.I.Taylor (1935) on the statistical theory. He applied to Cambridge to work with G.I. and persuaded his fellow-Australian Alan Townsend to join forces with him Brilliant combination of theory (GKB) and experiment (AA).



SS Umgeni, c. 1950
This was the ship they sailed in

GKB married Wilma Rätz in 1944, and they both set off for England in January 1945 by sea voyage (10 weeks) via New Zealand, Panama, Jamaica, New York, and then in convoy of 90 ships across the Atlantic, arriving Tilbury docks, London, April 1945;

...and found that G.I. didn't want to work on turbulence!

April 1945: GKB set to work in the basement Library of the Cambridge Philosophical Society

He later described how he came upon the papers of Kolmogorov (1941)

Like a prospector systematically going through a load of crushed rock, I suddenly came across two short articles, each about four pages in length, whose quality was immediately clear.

Fifty years with fluid mechanics. *Proc. 11th Australasian Fluid Mechanics Conference,* Dec. 1992, (Ed. Davies & Walker) pp 1-8

According to Barenblatt (2001), volumes of Doklady and other Soviet Journals were shipped from Murmansk to Scapa Flow in the Orkney Islands of the UK as ballast in ships on their return voyage, having carried armaments for besieged Russian cities on the outward voyage!

Batchelor presented his interpretation of Kolmogorov's work (and comparison with that of Onsager, Heisenberg and von Weizsäcker) at the Paris International Congress of Mechanics (September 1946); Paul Germain told me that the Proceedings of this Congress were duly delivered to Gauthier-Villars, but have not yet appeared; a record in publication delay??

But GKB published his paper in *Nature* (1946) and the full account in *Proc.Cam.Phil.Soc.*(1947)

His interpretation of the Kolmogorov theory was the basis of his worldwide reputation

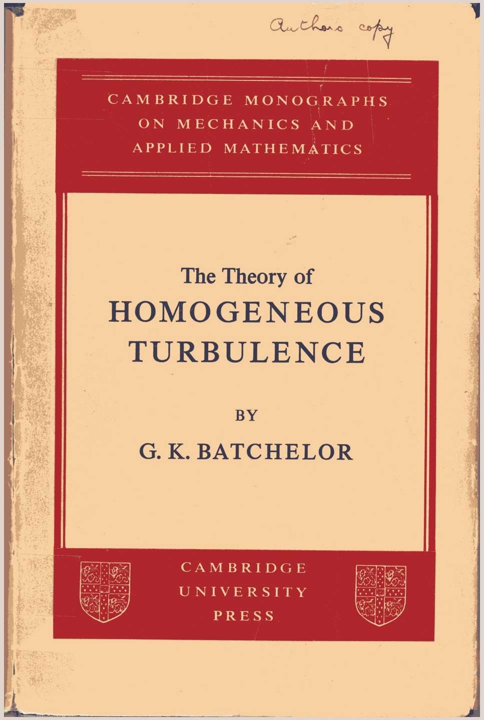
Elected Fellow of Trinity, 1947

GKB with his mentor and PhD supervisor G.I.Taylor, following the award of the PhD, Trinity College, Cambridge, 1948

From the Preface:

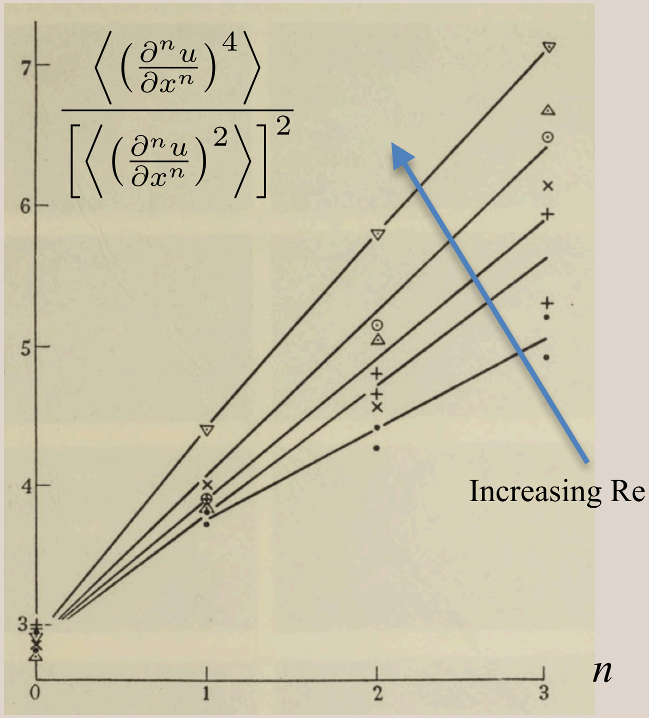
"In general, this dissertation represents super-structure built on the foundation work [of Sir Geoffrey Taylor] on the use of statistical theory and the significance of isotropic turbulence."

The Adams Prize 1952, led to Batchelor's research monograph *The Theory of Homogeneous Turbulence,* 1953



Dedicated "To G.I."

The first of the series "Cambridge Monographs on Mechanics and Applied Mathematics", edited by G.K.Batchelor and H.Bondi



This included (in the final section 8.5 of the book) a prescient discussion of intermittency, as first recognised by Batchelor & Townsend (1949)

"A case which offers us a better chance of observing the above [intermittency] effect is that of turbulent motion in two dimensions . . . "

This leads to a very preliminary discussion of two-dimensional turbulence, and the appearance and merging of concentrated vortices. Last page (186) of Batchelor (1953) anticipates the inverse cascade: he concludes that "there will gradually emerge a few strong isolated vortices and vortices of the same sign will continue to tend to group together", . . .

. . . . as confirmed by McWilliams (*JFM*, 1984) "The emergence of isolated coherent vortices in turbulent flow".

possible for the scale of the velocity distribution to increase. We expect, therefore, that from the original motion there will gradually emerge a few strong isolated vortices and that vortices of the same sign will continue to tend to group together. The differences between this motion and three-dimensional turbulence are very great, but the above argument suggests they have in common the property that the fluctuations in the velocity derivatives tend to occur in confined regions of space.

L. Onsager (1949) has arrived at a similar conclusion about the tendency for a small number of strong isolated vortices to form in a two-dimensional motion consisting of a random distribution of line vortices, from an argument based on the methods of statistical mechanics.

186

Batchelor returned to this problem in 1969

For a full account, see Moffatt (2012)
Homogeneous turbulence: an introductory review
J.Turbulence, **13**:1, N39

Kraichnan 1967 *Phys. Fluids,* **10**, 1417-1423 [Kraichnan's most cited paper]

Inverse cascade, as foreshadowed by Batchelor 1953

Inertial Ranges in Two-Dimensional Turbulence

ROBERT H. KRAICHNAN
Peterborough, New Hampshire
(Received 1 February 1967)

Two-dimensional turbulence has both kinetic energy and mean-square vorticity as inviscid constants of motion. Consequently it admits two formal inertial ranges, $E(k) \sim \epsilon^{2/3}k^{-5/3}$ and $E(k) \sim \eta^{2/3}k^{-3}$, where ϵ is the rate of cascade of kinetic energy per unit mass, η is the rate of cascade of mean-square vorticity, and the kinetic energy per unit mass is $\int_0^\infty E(k)\ dk$. The $-\frac{5}{3}$ range is found to entail backward energy cascade, from higher to lower wavenumbers k, together with zero-vorticity flow. The -3 range gives an upward vorticity flow and zero-energy flow. The paradox in these results is resolved by the irreducibly triangular nature of the elementary wavenumber interactions. The formal -3 range gives a nonlocal cascade and consequently must be modified by logarithmic factors. If energy is fed in at a constant rate to a band of wavenumbers $\sim k_i$ and the Reynolds number is large, it is conjectured that a quasi-steady-state results with a $-\frac{5}{3}$ range for $k \ll k_i$ and a -3 range for $k \gg k_i$, up to the viscous cutoff. The total kinetic energy increases steadily with time as the $-\frac{5}{3}$ range pushes to ever-lower k, until scales the size of the entire fluid are strongly excited. The rate of energy dissipation by viscosity decreases to zero if kinematic viscosity is decreased to zero with other parameters unchanged.

Kraichnan cites Batchelor (1953, p.186), in his opening paragraph

Batchelor (1969) on 2D turbulence and the enstrophy cascade

23 1969

Computation of the Energy Spectrum in Homogeneous Two-Dimensional Turbulence

G. K. BATCHELOR
Department of Applied Mathematics and Theoretical Physics
University of Cambridge, Cambridge, United Kingdom

Two-dimensional and three-dimensional turbulence have different properties, but both contain the two basic ingredients of randomness and convective nonlinearity, and some of the statistical hypotheses which have been proposed for three-dimensional turbulence should be applicable to two-dimensional motion. This justifies a numerical integration of the unaveraged equations of motion in two dimensions with random initial conditions as a means of testing the soundness of ideas such as those leading to the Kolmogoroff equilibrium theory. In spatially homogeneous two-dimensional turbulence, the mean-square vorticity is unaffected by convection and can only decrease under the action of viscosity. Consequently the rate of dissipation of energy tends to zero with the viscosity (ν). On the other hand, the mean-square vorticity gradient is increased by convective mixing, and it seems likely that the rate of decrease of mean-square vorticity tends to a nonzero limit χ as $\nu \to 0$. This suggests the existence of a "cascade" of mean-square vorticity at large Reynolds number, and an "equilibrium range" in the vorticity spectrum determined by the parameters χ and ν alone to which familiar dimensional arguments can be applied. Also, the energy and vorticity-containing components presumably settle down to an approximate similarity state determined by the total energy alone. A numerical integration of the equation of motion to test such similarity relations was attempted at Cambridge some years ago by R. W. Bray. The velocity distribution was represented by spectral lines at vector wavenumbers of the form (p, q), where p and q are integers and $(p^2 + q^2)^{1/2} < 10$, and the integration was carried out to times at which an appreciable amount of vorticity had been transferred to the larger wavenumbers. The results obtained with the rather small computing machine available at the time were not decisive, but they were consistent with the development of the expected k^{-1} form of the vorticity spectrum.

Growth of Batchelor's research group in the 1950s

The Cambridge turbulence research group, 1952,
Chris Nichol, Ian Proudman, Tom Ellison, Bill Reid
G.I.Taylor, George Batchelor

The Fluid Dynamics Group at the Cavendish Laboratory, 1955

Back Row: Ian Nisbet, Harold Grant, Anne Hawk, Philip Saffman, Bill Wood, Vivian Hutson, Stewart Turner
Middle Row: S.N.Barnes, David Thomas, Bruce Morton, Walter Thompson (G.I.'s technician), Owen Phillips, Freddie Batholomeusz, Roger Thorne
Front Row: Tom Ellison, Alan Townsend, Sir Geoffrey Taylor, George Batchelor, Fritz Ursell, Milton Van Dyke

Proudman & Reid 1954 On the decay of a normally distributed and homogeneous turbulent velocity field. ***Phil. Trans. A, R.S.*** **247,** 163-189

Batchelor & Proudman 1956 On The large-scale structure of homogenous turbulence. ***Phil.Trans.*****A 248,** 369–405

From USA: **Bill Reid, Milton Van Dyke, Chia Shun Yih, Andy Acrivos, . . .**
From Australia: **Alan Townsend, Bruce Morton, Owen Phillips, Stewart Turner, Adrian Gill, . . .**
From Poland: **Richard Herczynski, Waldek Fiszdon, . . .**
From Japan: **Tomomasa Tatsumi, . . .**
. . . .

Tomomasa Tatsumi with Marie Farge, Japan, 2015

Tomomasa Tatsumi and Hisashi Owada (now an Hon. Fellow of Trinity College) were the first visitors from Japan to Cambridge (1955) in the post-war years. Tomomasa was working then on the closure problem of turbulence, and is still actively engaged in this field.

Kolmogorov (1961)

A refinement of previous hypotheses concerning the local structure of turbulence in a viscous incompressible fluid at high Reynolds number

By A. N. KOLMOGOROV
Steklov Mathematical Institute, Academy of Sciences of the U.S.S.R., Moscow
(Received 10 December 1961)

The hypotheses concerning the local structure of turbulence at high Reynolds number, developed in the years 1939-41 by myself and Oboukhov (Kolmogorov 1941a,b,c; Oboukhov1941a,b) were based physically on Richardson's idea of the existence in the turbulent flow of vortices on all possible scales $l < r < L$ between the 'external scale' L and the 'internal scale' l and of a certain uniform mechanism of energy transfer from the coarser-scaled vortices to the finer. . . . .

GKB asked me to 'copy-edit' this paper, published in *JFM* 1962; from then on, I was 'hooked'. . .

. . . which takes me back to the Foundation of *JFM* six years earlier:

Foundation of *JFM* 1956

Volume 1, Part 1, May 1956

The JOURNAL of FLUID MECHANICS exists for the publication of theoretical and experimental investigations of all aspects of the mechanics of fluids, and is issued in six parts per volume.

Editor:
Dr. G.K. Batchelor, Cavendish Laboratory, Cambridge

Associate Editors
Professor W.C. Griffith, Princeton University
Professor G.F. Carrier, Harvard University
Professor M.J .Lighthill, Manchester University

Assistant Editors
Dr I. Proudman
Dr T. Brooke Benjamin

Average age of the team: 33!

George Keith Batchelor
1920-2000
Founder Editor of *JFM*
1956-2000
Aged 36 in 1956

Michael James Lighthill
1924-1998
Associate Editor of *JFM*
1956-1978
Aged 32 in 1956

Wayland Coleman Griffith
1925-2003
Associate Editor of *JFM*
1956-1988
Aged 31 in 1956

George Francis Carrier
1918-2002
Associate Editor of *JFM*
1956-1986
Aged 38 in 1956

Batchelor's involvement with IUTAM started at the Brussels Congress (1956) when he was appointed Secretary of the Congress Committee for the following Congress (Stresa 1960).

Brussels, 1956; Batchelor second from left; James Lighthill on the extreme right . . .

Batchelor and Lighthill: two dominant figures in fluid mechanics; but poles apart in personality and style. Lighthill held the Lucasian Chair in DAMTP, 1969-1978.

He continued as Secretary for subsequent Congresses, Munich (1964), Stanford (1968), Moscow (1972), and remained on the General Assembly of IUTAM till 1992.

. . . and at the Congress dinner (Sedov in front of GKB.)

Batchelor's involvement with China

1978: The General Assembly of IUTAM met in London, hosted by James Lighthill; China was represented by Zheng Zhemin and Wang Ren (Peking University); their presence at this gathering, just two years after the death of Mau Tsetung, made a dramatic impression.


Zheng Zhemin

Batchelor visited China in April 1980:

Shi, J.Z. (2020) George Keith Batchelor's interaction with Chinese fluid dynamicists and inspirational influence: a historical perspective. *Notes and Records of the Royal Society*
https://doi.org/10.1098/rsnr.2019.0034

"Batchelor made visits to China in 1980 and 1983. His first ice-breaking trip to China in April 1980 is of special importance to Sino-British fluid mechanics and to China . . ."


Zhou Peiyuan 周培源 in Cambridge, 1946 (photo provided by John Shi)

It was certainly important to me: I visited China in 1986, and had the great honour of dining with Zhou Peiyuan, then President of Peking University, in the Great Hall of the People.

Reprinted without change of pagination from the
Journal of Fluid Mechanics, *volume* 5, *part* 1, *pp.* 134–139, 1959

1959

(15)

Small-scale variation of convected quantities like temperature in turbulent fluid

Part 2. The case of large conductivity

By G. K. BATCHELOR, I. D. HOWELLS AND A. A. TOWNSEND
Cavendish Laboratory, University of Cambridge

(Received 1 July 1958)

The analysis reported in Part 1 is extended here to the case in which the conductivity κ is large compared with the viscosity ν, the conduction 'cut-off' to the θ-spectrum then being at wave-number $(\epsilon/\kappa^3)^{\frac14}$. It is shown, with a plausible and consistent hypothesis, that the convective supply of $\overline{\theta^2}$-stuff to Fourier components of θ with wave-numbers n in the range $(\epsilon/\kappa^3)^{\frac14} \ll n \ll (\epsilon/\nu^3)^{\frac14}$ is due primarily to motion on a length scale of order n^{-1} acting on a uniform gradient of θ of magnitude $[\overline{(\nabla\theta)^2}]^{\frac12}$. The consequent form of the θ-spectrum within this same wave-number range is

$$\Gamma(n) = \tfrac13 C\chi\epsilon^{\frac23}\kappa^{-3}n^{-\frac{17}{3}}.$$

The way in which conduction influences (and restricts) the effect of convection on the distribution of θ at these wave-numbers beyond the conduction cut-off is discussed.

It was shown in Part 1 (Batchelor 1959) that, when $\nu/\kappa \ll 1$, there is a convection subrange of wave-numbers defined by $L^{-1} \ll n \ll (\epsilon/\kappa^3)^{\frac14}$ within which the θ-spectrum has the form

$$\Gamma(n) \propto \chi\epsilon^{-\frac13}n^{-\frac53} \tag{1}$$

(the notation being everywhere as in Part 1). The direct effect of molecular conduction is unimportant at wave-numbers within this range, but becomes important when n is of order $(\epsilon/\kappa^3)^{\frac14}$. Over the more extensive inertial subrange of wave-numbers defined by $L^{-1} \ll n \ll (\epsilon/\nu^3)^{\frac14}$, the velocity spectrum has the form

$$E(n) = C\epsilon^{\frac23}n^{-\frac53}; \tag{2}$$

the direct effect of viscosity becomes important at wave-numbers of order $(\epsilon/\nu^3)^{\frac14}$, and causes $E(n)$ then to fall off much more rapidly than according to the power law (2).

The problem here is to find the form of the θ-spectrum at wave-numbers beyond those for which (1) is valid. Provided we confine attention to the wave-number range $L^{-1} \ll n \ll (\epsilon/\nu^3)^{\frac14}$—which is not a serious practical limitation, since wave-numbers of order $(\epsilon/\nu^3)^{\frac14}$ lie well beyond the conduction 'cut-off' of the θ-spectrum and the corresponding values of $\Gamma(n)$ will presumably be extremely small—the parameters relevant to the form of the θ-spectrum are ϵ, χ and κ, so that the general form of $\Gamma(n)$ is

$$\Gamma(n) = \chi\epsilon^{-\frac13}n^{-\frac53} \times \text{function of } (\kappa^{\frac34}\epsilon^{-\frac14}n),$$

Ian Howells was a research Fellow of Trinity College who later became a Jesuit Priest in Australia!

(16)

give the form of $\Gamma(n)$ in the region of transition from the power-law (1) to the power-law (9) at wave-numbers of order $(\epsilon/\kappa^3)^{\frac14}$ (where (1) and (9) do agree in giving the order of magnitude of $\Gamma(n)$ as $\chi\kappa^{\frac54}\epsilon^{-\frac34}$). However, neither of these limitations of the argument is of much importance. The available information about $\Gamma(n)$ is shown schematically in figure 1.

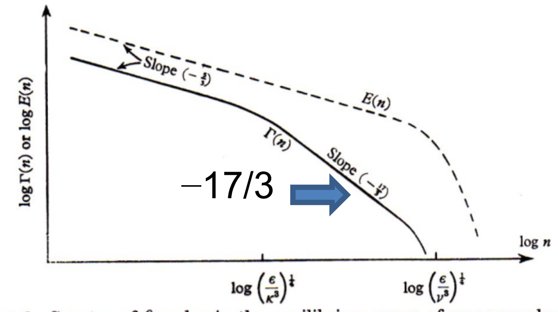


FIGURE 1. Spectra of θ and $\mathbf{u}$ in the equilibrium range of wave-numbers for the case $\nu \ll \kappa$.

It may be useful if we defend the argument against the possible objection that the contribution to the integral in (4) from small values of n' may actually be less than that from values of $\mathbf{n}'$ near $\mathbf{n}$. The mean square modulus of the latter contribution can be shown, by a calculation similar to that given for the former contribution, to be $\frac13\overline{\mathbf{u}^2}n^2B(\mathbf{n})\overset{*}{B}(\mathbf{n})$. It is possible to make $\overline{u^2}$ arbitrarily large, for fixed values of ϵ, χ, ν and κ, simply by increasing the length scale L in such a way as to keep $(\overline{\mathbf{u}^2})^{\frac32}/L$ constant, and by increasing $\overline{\theta^2}$ in proportion to $\overline{\mathbf{u}^2}$. Thus it would appear that, for any fixed n, $\overline{\mathbf{u}^2}$ could be made so large that the contribution from values of $\mathbf{n}'$ near $\mathbf{n}$ would dominate. However, the validity of the result which has been obtained is not affected, because in the circumstances in which this contribution from values of $\mathbf{n}'$ near $\mathbf{n}$ seems to be dominant the term $\partial B/\partial t$ is no longer negligible, and in fact cancels out this part of the integral. The reason for this is that the Fourier transforms are taken with respect to fixed axes, and the small-scale fluctuations in temperature, and the small eddies which cause them, are consequently being translated at a speed of order $(\overline{\mathbf{u}^2})^{\frac12}$ by the large eddies. The integral in (4) therefore has one part which expresses the rates of change of Fourier components due to observation from fixed axes, and one part which expresses the actual production of fluctuations of temperature at wave-number $\mathbf{n}$ to balance the conductive decay; thus we can ignore the term $\partial B/\partial t$, and the corresponding part of the integral in (4), and the calculation leading to (9) remains valid.

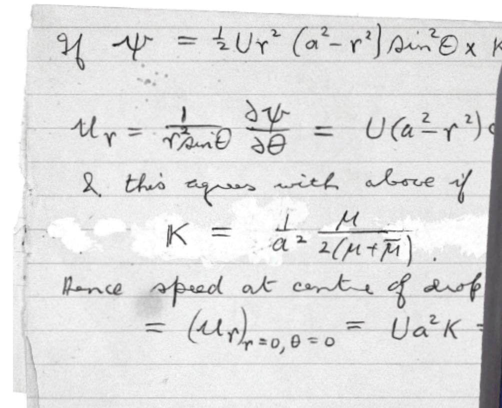
The above hypothesis about the interaction between the fields of $\mathbf{u}$ and θ may be given another interpretation, which is mechanically more direct and consequently more illuminating. It will be noticed from (7) that the interaction has been calculated as if equation (3) were replaced by

$$\mathbf{u}.\nabla T = \kappa\nabla^2\theta, \tag{10}$$

Photo: Howard Guest

Premises of DAMTP, Silver Street, 1964-2000

From 1962-1967, Batchelor focused on building up DAMTP and writing his textbook "Introduction to Fluid Dynamics"

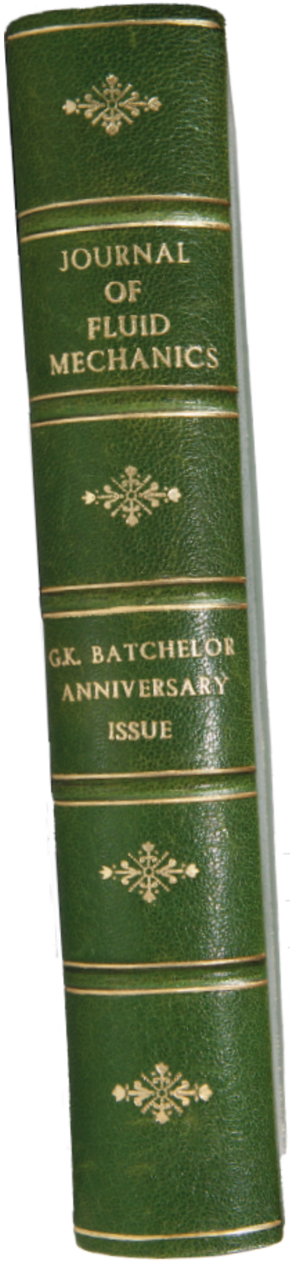


It was writing the sections of the book on low-Reynolds-number flows, concerning which this is one of his fragmentary revision notes, that Batchelor became increasingly involved in 'microhydrodynamics', the branch of fluid mechanics that he pioneered in the 1970s.

The author's own copy

1966: With a sigh of relief, George sets off for CUP from his home, Cobbers, with the ms of his book *An Introduction to Fluid Dynamics*, a textbook that now ranks with Lamb's Hydrodynamics as one of the great classics of the subject.

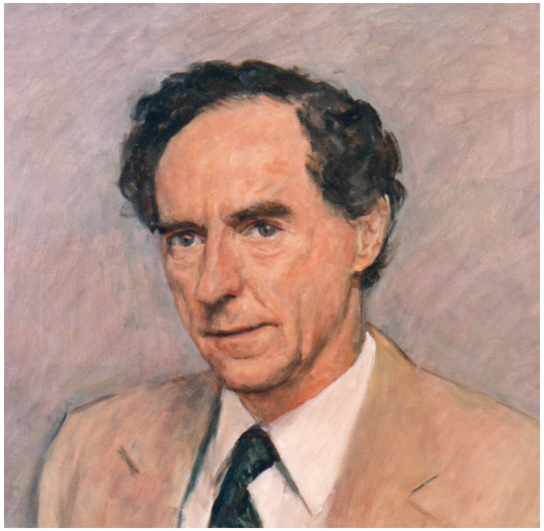
Published in 1967, this book was soon to establish itself as the bible of the subject for advanced University courses.



GKB's 70th birthday gathering in the old DAMTP, March 1990

Brooke Benjamin, Owen Phillips, Grisha Barenblatt, HKM
Akiva Yaglom, Andy Acrivos, GKB, Milton Van Dyke, Philip Saffman

The parallels between
George Keith Batchelor (1920-2000) and George Gabriel Stokes (1819-1903)



Portrait by
Rupert Shephard
1984

Lecturer 1948-1959
Reader in F.D. 1959-1964
Prof of Appl. Math. 1964-1983
Emeritus Prof. 1983-2000

Ed. *JFM*, 1956-2000

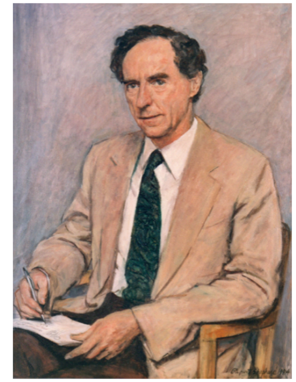
Lucasian Professor of Mathematics
1849-1897

Sec.R.S, and Ed. *Trans.* and *Proc. R.S.*
1854-1885

Both men were what could be described as *supremely conscientious*, with a strong personal commitment to the essential morality of science.

Both made seminal contributions to fluid mechanics, in Batchelor's case, to the theory of homogeneous turbulence, and later to microhydrodynamics, appropriately the application of Stokes's theory to suspensions of particles, drops or bubbles in fluids.

G K B



George Batchelor died on 30 March 2000. His portrait by Rupert Shephard hangs in the Department of Applied Mathematics and Theoretical Physics that he founded in 1959 and ruled as Head of Department until 1983, when I succeeded him. On 9th May 2004, we held a Reception in his honour, when an area with planted bottlebrush trees (Callistemon) from his native Australia was dedicated to his memory. I composed this sonnet to fit the occasion:

"I don't quite understand …", he used to say
In questing tone to which we lent our ears
At Friday seminars in the old Room A,
The ones he'd never missed in fifty years;

"I don't quite understand your line of thought
That leads you to these curves of rising slope
Which fail to go to zero as they ought;
Perhaps you've lost a sign, or so I hope!"

The speaker, blanched and halted in his tracks,
Would stammer "Well, I hadn't noticed that"
(Thinking, O God, my theory's full of cracks)
"Let's leave these curves for later private chat".

So then would G K B with patient tact
Convey the insight that the treatment lacked.

Conclusion

George Batchelor will be remembered as a man of great scientific integrity, penetrating judgement and deeply held convictions. He considered the pursuit of natural knowledge as “a civilising and ennobling activity” on which he wrote:

“Through having common objectives and principles by which new knowledge is assessed and disseminated, scientists concerned with a particular field like fluid mechanics form an international community of great unity and moral strength. I believe that the understanding, trust and goodwill between members of this scientific community transcends geographical and political boundaries and constitutes one of the most important forces for international harmony and friendship in the world today.”

From “Research as a life style” Appl. Mech. Rev. 50, R11-R20 (1997)

Let’s drink a virtual toast to the memory of George Batchelor and the trust and goodwill that he always endeavoured to promote