Superfluidity: three people, two papers, one prize

Most accounts of the controversial discovery of superfluid helium by Peter Kapitza, Jack Allen and Don Misener are often incomplete or simply wrong. **Allan Griffin** tries to set the record straight

University of Toronto

Misener family collection

Three of the best
Peter Kapitza (left) was awarded one half of the 1978 Nobel Prize for Physics for the discovery of superfluidity 40 years earlier. Jack Allen (middle) and Don Misener (right) discovered the phenomenon at the same time but did not get the same recognition.

The discovery of superfluidity in liquid helium-4 was announced to the scientific world on 8 January 1938, when two short papers were published back to back in *Nature*. One was by Peter Kapitza (*Nature* **141** 74), the director of the Institute for Physical Problems in Moscow, and the other was by two young Canadian physicists, Jack Allen and Don Misener (*Nature* **141** 75), both working at the Royal Society Mond Laboratory at the University of Cambridge in the UK. Both studies reported that liquid helium flowed with almost no measurable viscosity below the transition temperature of 2.18 K.

Very soon afterwards, theoretical work by Lev Landau, Fritz London and Laszlo Tisza showed that this zero viscosity was evidence for a new superfluid phase of matter. We now understand that superfluidity is associated with the motion of a Bose–Einstein condensate. As a result, the quantum liquid exhibits macroscopic quantum effects that are visible to the eye, such as the ability of the liquid to flow up and out of a container and the famous fountain effect. Superfluid helium also became the testing ground for theories about collective behaviour in quantum many-body systems.

Although the discovery of superfluidity stands as one of the most significant in physics in the 20th century, it was to be 40 years before the Royal Swedish Academy of Sciences honoured this seminal discovery with a Nobel prize – an exceptionally long interval. In 1978 Kapitza, by then 84, was given half of that year's Nobel Prize for Physics with a somewhat vague citation reading "for his basic inventions and discoveries in the area of low-temperature physics". The other half did not go to Allen and Misener. Indeed, apart from a single mysterious sentence in the longer Nobel citation, the work of the two Canadians was completely ignored.

In his Nobel address Kapitza broke with tradition and said nothing about the work on superfluid helium for which he was being honoured. Instead, on the grounds that he had abandoned work on low-temperature physics decades earlier, he reviewed his most recent research on thermonuclear reactions. Today, science popularizers generally give sole credit for the discovery of superfluidity to Kapitza. The international low-temperature community generally also gives equal credit to Allen and Misener, but until very recently their work was never mentioned in the Russian literature.

From Russia to Cambridge...and back again

Kapitza, a native of Russia, arrived at Cambridge as a student in 1921 to work at the Cavendish Laboratory under the supervision of Ernest Rutherford and remained there until 1934. The young Kapitza showed a talent for innovative experimental techniques and for pushing technology to the limits. With his outgoing, charismatic personality and enormous self-confidence, Kapitza developed into a brilliant physicist who

Allan Griffin is in the Department of Physics, University of Toronto, Canada, e-mail griffin@physics.utoronto.ca

The Cavendish Laboratory

St Andrews University

Scene of the action The Mond Laboratory at Cambridge (left) where Kapitza worked until 1934. Allen arrived at the lab in 1935 (pictured right with Mond Lab staff, including Cockcroft, in 1938).

throughout his life impressed and charmed people as diverse as Rutherford, Paul Dirac and, in later years, the Soviet leader Joseph Stalin.

Kapitza's talents were quickly recognized by Rutherford and others, and he soon advanced to a leadership role at the Cavendish. In 1933 the Royal Society used a bequest from the German-born chemist and industrialist Ludwig Mond to build a new laboratory to enable Kapitza to study the effect of very high magnetic fields on the electronic properties of metals at low temperatures. This research led to Kapitza's interest in developing a more efficient and safer way of producing large quantities of liquid helium for use as a cryogenic fluid. The liquefaction of helium had first been achieved in July 1908 by the Dutch physicist Heike Kamerlingh Onnes at the University of Leiden, the centenary of which will be celebrated at the 25th International Conference on Low Temperature Physics in Amsterdam this month.

Starting in 1932, Kapitza developed a new kind of liquefier based on gas expansion rather than using liquid hydrogen as an intermediate step. He first produced liquid helium with his new liquefier in April 1934. His innovative design soon made it possible for many other laboratories to produce liquid helium easily, effectively giving birth to the new field of low-temperature physics.

A huge setback came when Kapitza was "detained" in Moscow in September 1934 during one of his regular visits to the Soviet Union to see his family. His Soviet passport was retained by the authorities and he was not allowed to leave the country. Instead he was asked to set up a major new laboratory funded by the Soviet government. With little option, Kapitza accepted his fate with a heavy heart, and proceeded to create the Institute for Physical Problems in Moscow. To speed up the process of setting up the new laboratory, he requested help from the Cavendish. Rutherford and John Cockcroft, both close friends and colleagues of Kapitza, arranged to send equipment and supplies needed to build a new laboratory and liquefier. Even more importantly, two senior technicians from the Mond Laboratory were transferred to Moscow to work with Kapitza for several years.

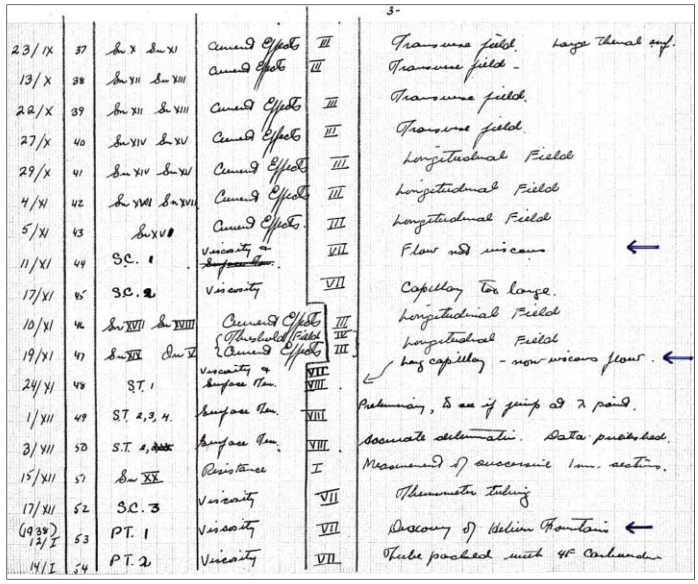
The abrupt disappearance of Kapitza threw the low-temperature group at Cambridge into a state of turmoil. In an attempt to keep the research effort going, in August 1935 Rutherford invited Jack Allen to come to the Mond Laboratory. Allen had received his PhD two years earlier at the University of Toronto and was already a seasoned researcher in superconductivity having worked with John C McLennan, an old friend of Rutherford during the latter's time in Canada. McLennan had built up a major low-temperature laboratory that successfully produced liquid helium in 1923 based on Onnes' liquefier design developed in 1908, thus making Toronto the second laboratory in the world to accomplish this feat. Indeed, in the decade between 1923 and 1933 the Leiden and Toronto laboratories dominated research in low-temperature physics using liquid helium.

Same discovery, same time, different places

Despite Allen's reputation and qualifications, Rutherford's invitation was somewhat forbidding: no funding was offered initially, but there was the promise that once Allen proved his worth he would be paid one half of Kapitza's original salary. Allen arrived in Cambridge in the autumn of 1935 – a time when the Mond Laboratory was preoccupied with sending senior technicians, equipment and other assistance to help Kapitza set up his new lab in Moscow. Fortunately, Kapitza's original liquefier was still available and providing a reliable supply of liquid helium. Allen's "take charge" personality thrived in this atmosphere, which he later called a "civilized jungle". While Cockcroft was acting head of the lab, Allen became the de facto leader of the group working with liquid helium. Soon, the pay cheques began arriving.

A year later, in 1936, Don Misener arrived at Cambridge to do his PhD, having been awarded a prestigious "1851 Exhibition Scholarship". He also came from the University of Toronto, where he had just carried out a groundbreaking experiment that involved measuring the shear viscosity of liquid helium just below the transition temperature using the decay time of the torsional oscillations of a rotating cylinder immersed in the liquid. He found that the viscosity decreased sharply as the temperature went below the


The Cavendish Laboratory


University of Toronto

Cool customers
Allen with the apparatus he used to measure the viscosity of superfluid helium (left). Misener kept a detailed log book (right) of all the experiments that he performed, leading up to the discovery of superfluidity.

transition threshold. This provided the first evidence that helium-II (the low-temperature phase) exhibited behaviour quite different from a classical fluid (*Proc. R. Soc.* A **151** 342).

In 1937 Allen and co-workers made a groundbreaking study of the thermal conductivity of superfluid helium in thin glass capillaries. The rate of heat transfer was found to be very large and quite anomalous, in that it was not proportional to the applied temperature gradient. The resulting paper (*Nature* **140** 62) had a big impact on the growing research community studying liquid helium, and was certainly noted by Kapitza in Moscow.

Later that year Misener joined forces with Allen to measure the viscosity of superfluid helium flowing in thin glass capillaries. Under the terms of Misener's scholarship, he was required to write yearly reports on the progress of his PhD research. At the end of his 1938 report, Misener included a handwritten log of all his helium experiments made at the Mond Laboratory. On 11 November 1937 the first viscosity experiments are noted. Finally, "non-viscous" flow was detected in a thin glass capillary on 24 November. This can be taken as the day Allen and Misener discovered superfluidity.

Superfluid helium arrives at *Nature*

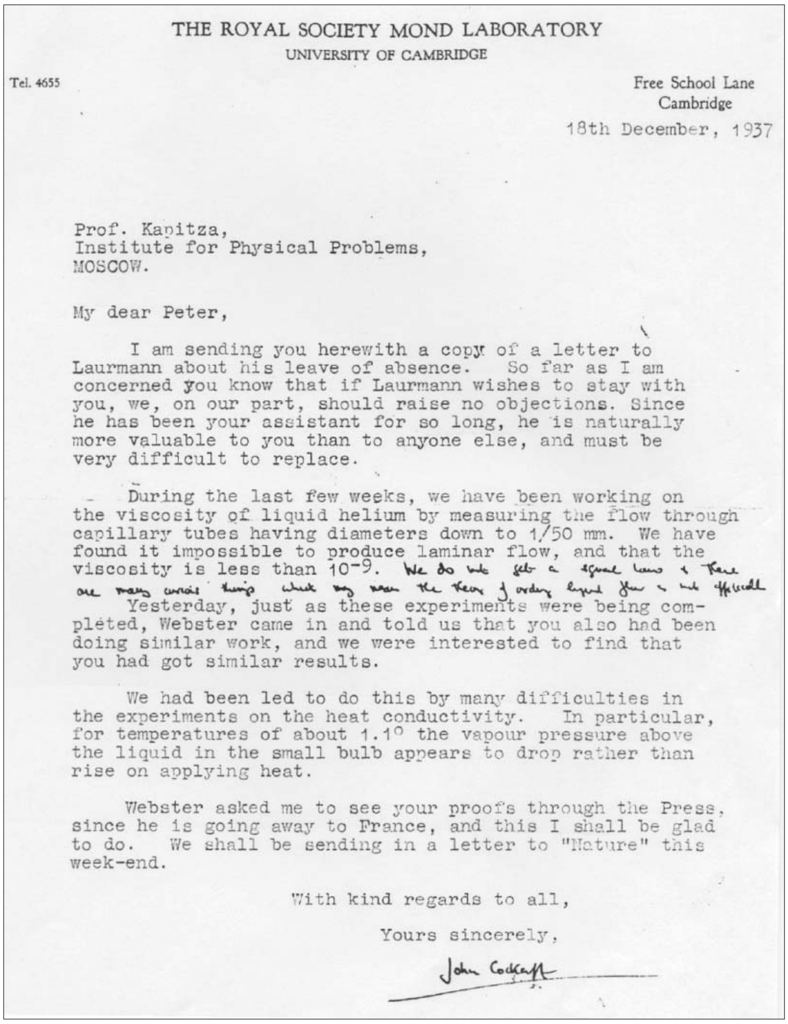
Just before Christmas that year, on 17 December 1937, William Webster dropped in at the Mond Laboratory. Webster, another Canadian physicist from Toronto and an old friend of Allen, had been Kapitza's first graduate student at Cambridge. He had just returned from visiting Kapitza in Moscow and came to inform Cockcroft of Kapitza's new results: the Russian had also discovered superfluidity and his paper had been already been received by *Nature* two weeks earlier, on 3 December.

The news must have come as a bombshell. Cockcroft and Kapitza were close personal friends and colleagues, and they exchanged letters frequently at that time. It must have seemed strange to Cockcroft that this new research had never been mentioned by Kapitza. Cockcroft immediately instructed Allen to write up the work with Misener, and the next day (18 December) he wrote to Kapitza telling him about similar zero-viscosity results obtained at Cambridge in the preceding weeks. Allen and Misener submitted their own paper to *Nature* on 21 December. On Christmas Day Cockcroft sent another letter to Kapitza saying that he had returned the latter's corrected proofs to *Nature*, as he had been requested to do so by Webster.

Cockcroft's letter to Kapitza on 18 December shows that the Cambridge group had no prior knowledge of Kapitza's research. On the other hand, Kapitza had kept Niels Bohr in Copenhagen up to date with his research plans and informed him of his zero-viscosity results on 10 December. In his submission letter to *Nature*, Kapitza was also very insistent that the precise submission date be recorded and that the paper be published as soon as possible. Webster's visit to the Mond Laboratory must have been with the full approval of Kapitza, and it had the effect of compromising the independence of any paper that might be under preparation by Allen and Misener. All of this strongly suggests that Kapitza was worried about being "scooped" by the two young Canadians, his only possible competitors.

One can sympathize with Kapitza for not wanting to share the honours of this discovery, the first major one made at his new laboratory in Moscow. The fact that a Soviet laboratory could beat the efforts of capitalist countries was viewed very favourably in the highest echelons of the Soviet government. The discovery of superfluidity certainly helped strengthen the position of Kapitza at what was a dangerous time in the Soviet Union. In March 1938 the KGB secret police arrested the brilliant Soviet theorist Lev Landau. Overcoming the objections of the KGB, Kapitza

Without the stimulus of the earlier work of both Allen and Misener, it is doubtful whether Kapitza would ever have become interested in measuring the viscosity of helium-II or have received the Nobel prize


THE ROYAL SOCIETY MOND LABORATORY
UNIVERSITY OF CAMBRIDGE

Tel. 4655

Free School Lane
Cambridge

18th December, 1937

Prof. Kapitza,
Institute for Physical Problems,
MOSCOW.

My dear Peter,

I am sending you herewith a copy of a letter to Laurmann about his leave of absence. So far as I am concerned you know that if Laurmann wishes to stay with you, we, on our part, should raise no objections. Since he has been your assistant for so long, he is naturally more valuable to you than to anyone else, and must be very difficult to replace.

During the last few weeks, we have been working on the viscosity of liquid helium by measuring the flow through capillary tubes having diameters down to 1/50 mm. We have found it impossible to produce laminar flow, and that the viscosity is less than 10^{-9}. We do not get a square law & there are many curious things which may mean the theory of ordinary liquid flow is not [illegible]

Yesterday, just as these experiments were being completed, Webster came in and told us that you also had been doing similar work, and we were interested to find that you had got similar results.

We had been led to do this by many difficulties in the experiments on the heat conductivity. In particular, for temperatures of about 1.1° the vapour pressure above the liquid in the small bulb appears to drop rather than rise on applying heat.

Webster asked me to see your proofs through the Press, since he is going away to France, and this I shall be glad to do. We shall be sending in a letter to "Nature" this week-end.

With kind regards to all,

Yours sincerely,

John Cockcroft

St Andrews University

Between friends
Cockcroft wrote this letter to Kapitza after finding out that the latter had already reported superfluidity and had sent a paper to *Nature*. Allen and Misener had obtained similar results but had yet to write up the work.

was able to use his new status with Stalin to have Landau released from prison in 1939 on the grounds that Landau was needed to explain the newly discovered phenomenon of superfluidity.

Nobel dispute

It was to take 40 years for the call to come from Stockholm. There is considerable evidence that, during that period, many senior low-temperature physicists, such as the two-time physics Nobel laureate John Bardeen, recommended that Kapitza and Allen share a Nobel prize. As he was still a graduate student, Misener would not have been considered as a candidate (a tradition that has changed in recent years). However, there is also evidence that Kapitza indicated that he would not accept the award if it had to be shared with Allen, and this is probably the main reason for the long delay. Stories of this kind are mentioned by Russian physicists, but only off the record.

In 2002 the late David Shoenberg, the distinguished low-temperature experimentalist at Cambridge University who was in close contact with both Kapitza and Allen in 1937 and in the decades that followed, sent an e-mail to the current author that confirms these rumours. Although Shoenberg said that he knew "nothing about the inside politics of the Nobel prize", he added in a postscript that a Russian physicist friend of his then in Cambridge but who had been close to the work in Moscow had just confirmed that "Kapitza was approached by the Nobel people and said that he would not accept a joint award with Allen".

While we can understand Kapitza's attitude in the years immediately following 1938, it is more puzzling why he would not want to recognize the work of Allen and Misener in later decades. He might have felt it demeaning to share the Nobel prize with Allen, who at the time of the discovery was very much his junior. One would think that this stance might have softened in later years, when Allen became the doyen of the international low-temperature-physics community.

Another reason might be that Kapitza always viewed the Mond Laboratory as his creation. Since Allen and Misener were junior researchers using these facilities, Kapitza could well have considered them as part of his own "extended" research group. If this is true, of course, it puts Kapitza in the strange position of competing against junior members of his own group. That Kapitza felt that the lab to be his, even while he worked in Moscow, is evident in letters he wrote to his wife. This feeling would have been strengthened by the willingness of Rutherford and Cockcroft to make considerable efforts to help his research in Moscow. By the same token, Cockcroft, Dirac and other senior physicists at Cambridge must always have found it difficult to promote the independent work of Allen and Misener knowing the feelings of Kapitza, their friend and colleague.

To view Allen as a junior researcher who took advantage of facilities that Kapitza had built up is, however, unjust. Even at 27 years of age, when he first arrived in Cambridge, Allen was already a resourceful experimentalist and experienced in working with liquid helium. Allen had no choice but to work in a laboratory that was being "stripped" in order to help set up Kapitza's new initiative in Moscow. In spite of this, Allen carried out a series of brilliant experiments delineating the nature of superfluidity in liquid helium in the years 1937 to 1939, including observing the fountain effect in 1938 (*Nature* **141** 242) just four days after his paper with Misener was published. This is one of the most spectacular manifestations of the "two-fluid" nature of superfluid helium.

An often overlooked feature of Kapitza's famous paper is that all three references are to earlier research papers published by Allen, Misener and their co-workers. In addition, the first two paragraphs of Kapitza's short paper are devoted to criticism of Misener's measurement of the viscosity in 1935 (*Nature* **135** 265; *Proc. R. Soc.* A **151** 342). Without the stimulus of the earlier work of both Allen and Misener, it is doubtful whether Kapitza would ever have become interested in measuring the viscosity of helium-II or have received the Nobel prize. The subsequent treatment of the young Canadian researchers is a sad aspect of one of the greatest discoveries in physics. It is encouraging, however, that in the last decade their contribution is being acknowledged more universally.

Allen and Kapitza never corresponded with each other, and met just once at a conference in Moscow in 1966. We can only imagine what they might have talked about during that encounter. ■

● For a longer version of this article with additional references see www.physics.utoronto.ca/~griffin