John S. Briggs

Die verlorene Zeit

The members of the study group "The Meaning of Time in Quantum Theory" were John S. Briggs, Lajos Diósi, Martin Gutzwiller (two months), Claus Kiefer (one month) and Jan-Michael Rost (seven months). The aim of the research was to study the way in which time enters the quantum theory at the most fundamental level. This involves the question of how time arises through the interaction of a system with its environment and how time is defined in the most sophisticated of physical theories, the quantum theory of fields and its generalisation to a quantum theory of gravity. This is a very broad programme and the members of the study group had been chosen on the basis of the complementary expertise which they could bring across the spectrum of quantum theory.

Specifically, Briggs, Rost and Diósi worked on the quantum mechanical aspects using essentially the wave equations of Schroedinger and their derivatives. Gutzwiller looked at the role of time in the first and best known of quantum field theories, the quantum electrodynamics (QED) of electrons and photons. Kiefer broadened the perspective to include the most fundamental theory in which space itself is quantised to try to include gravity as a quantised field. In this way these three main themes represented a natural progression in complication and abstraction.

Briggs and Rost attacked the accepted wisdom of countless textbooks that time is absolute and equivalent to a space co-ordinate, by showing that time can be always derived by dividing a time-independent closed quantum system into two parts and allowing one part, called the environment, to become so large that it can be described by classical equations of motion. This part then defines the time parameter for the remaining quantum system via the interaction of the system with this environment. Without interaction there is no time.

This question was taken considerably further in Diósi's research. He considered the interface between classical and quantum systems in detail; problems that have much relevance for measurements on microscopic quantum systems using macroscopic measuring devices. Diósi was able to show precisely how a classical environment couples to quantum dynamics.

This aspect of measurement at given times has long been a fundamental problem of field theory and QED in particular. Martin Gutzwiller tried to resolve an old problem found in many textbooks on QED that certain processes cannot be followed in a time picture and that only global prob-

abilities for these processes can be given, dependent upon boundary conditions in the distant past and future. In some sense this search for lost time is similar to the efforts of Briggs and Rost to identify time in the Schroedinger approach.

This problem of time in field theory assumes even more importance in the research of Claus Kiefer on the quantisation of general relativity. Here the basic equations describing gravity and matter fields in the universe are time-independent; for the universe as a whole, there is no time. In a series of lectures Kiefer was able to show that, in a semi-classical approximation to the gravity field, time and space-time can be restored. It was the major success of the group's work to see how the mathematical methods used to introduce time into a timeless universe are exactly the same as those used by Briggs and Rost to introduce time into a timeless closed microscopic quantum system. This surprising feature led to much interesting exchange of ideas in the last weeks of the programme and will be the subject of future collaboration between the participants.

The first few weeks of the group's work, in October and November, were taken up by many discussions and exchanges on a daily basis, augmented by more formal seminars which, however, usually degenerated into heated arguments which often disturbed our neighbours from biology in the Villa Jaffé. The first months of the new year were used more for separate study on the three main topics and it was during this time that the paper of Briggs and Rost, on *Time in Quantum Mechanics*, and the papers of Diósi and collaborators, on the *Royal Road to Coupling Quantum* and *Classical Motion*, were formulated and written up.

Coinciding with the return of Gutzwiller, the month of April was one of extreme activity. Although the planned International Workshop was not approved, nevertheless it was possible to hold a mini-workshop consisting of ten lectures during the last ten days of April. Not only were three guests, Harvey Brown of Oxford University, Julian Barbour from England and Walter Strunz from Essen present at this time, there was also regular attendance at the seminars of colleagues from several Berlin research groups.

The philosopher Harvey Brown contributed greatly to broadening the scope of our thinking on time by explaining current philosophical ideas on this subject. Strunz worked with Diósi on their joint paper as well as giving his lectures on stochastic Schroedinger equations. Above all, Julian Barbour enlivened the group's work by provoking endless discussions on the deeper aspects of time in classical and quantum physics. Barbour is a world-renowned author on the subject of time through his classic work, *Absolute or Relative Motion* and his forthcoming book *The End of Time*. Not only did he lecture in Wiko, he was also in demand at the MPI

for Gravitational Physics in Golm and the Astrophysical Institute in Potsdam.

In fact all members of the group fostered many contacts to institutions in the Berlin region and held colloquia or seminars there. Following a newspaper article on the group's work, contact was made to Prof. Gerald Ulrich of the Psychiatric Clinic at the FU Berlin and to em. Prof. H.-J. Treder at the Physics Institute at Potsdam University. Both these gentlemen have a long-standing interest in time and the philosophy of physics. The whole group spent an interesting afternoon in Potsdam at the invitation of Prof. Treder. Other frequent visitors to our weekly seminars at Wiko were, Prof. Gebhard v. Oppen (TU), Prof. Bernd Esser (HU) and Prof. J. Louko (MPI, Golm b. Potsdam). Two public lectures of general interest were held, by Martin Gutzwiller in the Thursday evening Wiko lecture on the Moon and its history, and by John Briggs at Urania on the concept of motion in atoms.

The results of the group's researches on time are available as reprints and will be published, mostly in the *Physical Review.*