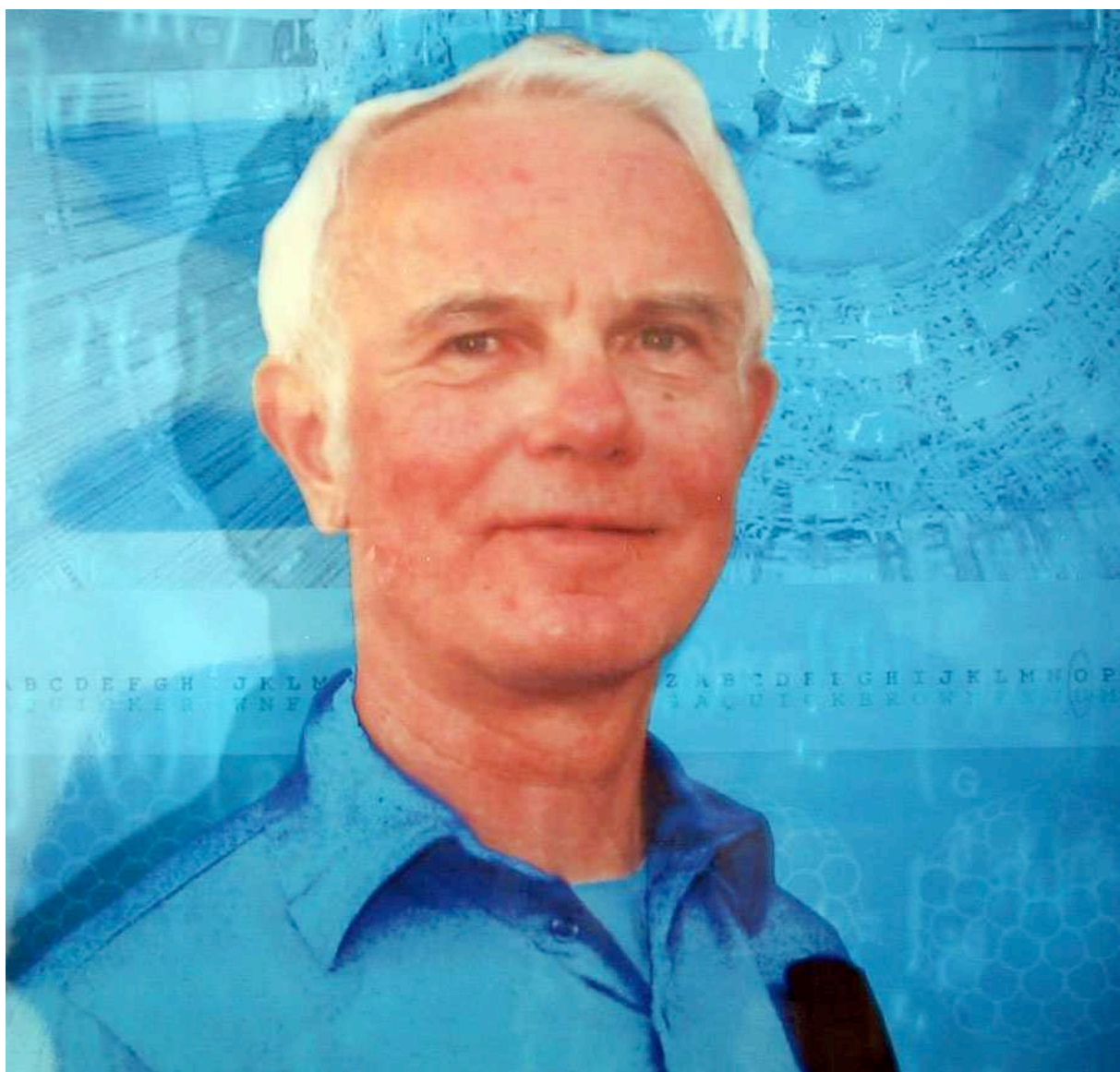


Vicissitudes of Research^{*}

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Mike Cornwall and I have maintained a long-distance friendship for almost thirty years. It must be a strong friendship indeed, because we have not seen each other for about twenty years.

Our interaction consisted of collaborative physics research that resulted in several joint papers, which we wrote during mutual visits: mine to Los Angeles, Mike's to Boston.

I remember very fondly coming to the West Coast, with my then-eleven-year-old son Nicholas. He too developed a great admiration for Mike because of the magic stories and tricks that Mike taught Nicholas.

Recently Mike came to Boston for an event similar to this one, staying at the Plaza Hotel. The hotel has an associated magic story: It is said that Houdini kept a room there for a time. When a while ago my magic-smitten son heard this, he was most impressed. This allowed me to concoct an April Fool's trick on him. The hotel was being rebuilt and I told Nicholas that the construction workers came upon a hidden and forgotten closet containing novel and heretofore secret Houdini paraphernalia. Nicholas believed the tall tale, and didn't connect it with April fooling until he insisted on going to the hotel to examine the treasure trove. Then I had to come clean.

So in this way Mike's hobby contributed to family merriment!

But the foundation for Mike's and my association is our physics research. I want to describe this to you briefly, and also to observe how research is accepted and appreciated in our community. There are three pieces of work to discuss.

Our first paper comes out of the old subject of current algebra. This technique, by now forgotten by many and unknown to many more, was the principal tool for developing information about particle physics, at a time when we had no knowledge of the operative dynamical laws. Gell-Mann proposed that the group theoretical structure of the equal-time commutators of currents could be used to derive various experimentally testable facts. This was a brilliant generalization from the situation in quantum mechanics, where various sum rules for physical amplitudes (Thomas-Reiche-Kuhn, Bethe) can be derived solely from the equal-time Heisenberg algebra of the canonical variables, without specification of dynamics.

However, it soon became clear that the algebraic results made contact with observable sum rules only in a frame moving with infinite momentum. So Fubini suggested that Lorentz invariance be invoked to relate them to rest-frame quantities. Unfortunately manipulations at infinite momentum involved uncontrollable steps, which occasionally produced absurd sum rules that were falsified in explicitly solvable toy models (Bj sum rule).

Next came a contribution from Kogut and Soper, who, following a suggestion by Dirac, showed that canonical quantization need not be carried out at equal times on space-like surfaces, but could alternatively be performed, just as validly, on light-like surfaces.

Their observation suggested to Mike and me that we should use this so-called “light-cone quantization” to construct a light-cone algebra of currents, and use this algebra for an alternative derivation of the sum rules. This we did, and were delighted to discover small but significant differences between the equal-time algebra and the light-cone algebra. And these differences fixed the shortcomings of the infinite momentum approach!

So we wrote a paper, and I was very optimistic about its fate. But in fact the response of the community was tepid. What happened was that physics moved on from current algebra to new topics, like deep-inelastic scattering, partons, Veneziano model and ultimately the standard model. And as is usual, imperfections in past theoretical structures were ignored, with the conviction that even if all is not well, it doesn’t matter. So our paper, which Spires calls “very well known” because it received more than 100 citations, came too late to influence the subject. By the time we solved the problem very few cared!

One person did care, Fubini. He was delighted with our “fix” and discussed it at length in his thick book “Currents in Hadron Physics,” which regrettably is also mostly unread. Moreover, Fubini became my colleague and friend at MIT, and initiated a close collaboration with Italian physicists, which is still flourishing.

The second collaboration with Mike was virtual. In fact he performed the research separately with Dick Norton and I with Ken Johnson. But we consulted each other and published our separate papers in the same volume of Physical Review D, establishing the same results.

Here the issue was the spontaneous breaking of local gauge symmetry, a central topic for the standard model. Even though Anderson and Schwinger established the feasibility of this happening due to dynamical instabilities in the bound-state spectrum, the models that they considered were far removed from realistic particle physics. The favored particle physics approach relies on an additional field, the Higgs-Kibble (etc.) scalar field, whose postulated instabilities break a global symmetry, which in the presence of gauge fields results in local gauge symmetry breaking, without mass less Goldstone bosons. But there remains hope that one can dispense with elementary scalar fields and their postulated instabilities, replacing them with a dynamical bound-state mechanism, a la Anderson and Schwinger, but in a realistic setting for particle physics.

Nambu had already shown how a dynamical mechanism could lead to spontaneous global symmetry breaking and mass less Goldstone bosons. Our quartet demonstrated how to include gauge fields and that in their presence the dynamically generated Goldstone bosons decouple.

Although we succeeded in the formal demonstration, we could not construct a phenomenologically viable model for particle physics. Nevertheless, our work became “very well known” and even “famous” according to Spires, which recorded about 300 citations per paper, making this the most cited collaboration between Mike and Dick as well as between Ken and me.

Some years later Weinberg constructed his model for dynamical symmetry breaking, and credited our work for establishing the feasibility of the mechanism, but he too could not produce a realistic theory; nor could Susskind who still later also tried with his “technicolor” models (but without acknowledging our earlier results).

Today physicists take an agnostic attitude toward the question whether spontaneous gauge symmetry breaking arises from a bound state dynamical mechanism. Although I was pleased that we could illuminate important aspects of the problem, it is also clear that our papers were too early and too indefinite to convince our readers. We now await with great hope decisive news from the LHC.

While the first effort came too late and the second was too early, our third enterprise was timed just right. When discussing dynamical gauge symmetry breaking, Mike and I decided that a rich depository of expertise on that topic resided within condensed matter physics, where the order parameter – an analogue of the Higgs field – is taken to be elementary only in effective, macroscopic descriptions, like Landau’s, while from a microscopic point of view it is a dynamically bound composite entity, like a Cooper pair. The formalism that is employed in these studies makes use of gap equations for composite operators.

So Mike and I decided to transport this formalism from its condensed matter context to the relativistic particle physics framework. Mike was visiting Boston at that time, and we engaged the excellent – then my student – Terry Tomboulis to assist us. We produced our paper, with which I was satisfied, but unlike with the others, not overwhelmingly impressed, because it merely translated knowledge from one field to another.

But apparently the particle physics community was eager to obtain this knowledge, because our paper enjoyed tremendous success – becoming “renowned” according to Spires, with almost 1000 citations.

There were further benefits from this effort. The UCLA people became acquainted with Tomboulis, hired him, and he still graces the department. For me, the initial contact with condensed matter physics developed to the point that I could contribute original ideas, like the fractional charge phenomenon that I described in my colloquium.

From these three vignettes about our research efforts and impact I learned that you never know if the “time is right” for your ideas. Best to follow them wherever they lead and not try to fit them into prevailing winds of activity, since you cannot predict what benefits will reward your efforts.

Happy Birthday Mike and Greetings to Ingrid!

Canonical Light-Cone Commutators*John M. Cornwall[†] and R. Jackiw^{†‡}*Department of Physics, University of California, Los Angeles, California 90024*

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We study the canonical structure of current commutators on the light cone, as embodied in Kogut and Soper's formulation of quantum electrodynamics in the infinite-momentum frame. These commutators incorporate dynamical information far beyond that contained in conventional equal-time commutation relations. An analog of the Bjorken-Johnson-Low limit is developed for calculating matrix elements of light-cone commutators from conventional time-ordered products. Some apparently new sum rules for electroproduction are obtained. They relate Fourier transforms of structure functions to bilocal products of operators. We suggest possible directions for constructing phenomenological light-cone commutators in hadronic physics. These commutators can be used to describe entire Regge trajectories, and might find application to electroproduction and neutrino-induced production experiments.

Dynamical Model of Spontaneously Broken Gauge Symmetries*

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We demonstrate how a theory consisting of massless Fermi and vector-meson fields can lead to an excitation spectrum of solely massive particles. We eschew spinless Bose fields in the fundamental Lagrangian, contrary to current practice. A detailed model is presented and solved in lowest order. Fermion and axial-vector-meson masses are spontaneously generated, and the vector particle's mass is computed in terms of the fermion mass.

Spontaneous Symmetry Breaking Without Scalar Mesons*John M. Cornwall[†] and Richard E. Norton*Department of Physics, University of California, Los Angeles, California 90024*

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By combining the ideas of Nambu in his study of superconductivity and of Johnson, Baker, and Willey in their approach to electrodynamics we construct a gauge theory of spontaneous symmetry breaking which is free of elementary spin-zero fields. The theory contains two fermions and two vector mesons, one of which acquires a mass via the Higgs mechanism. A formula for this vector-meson mass is derived which becomes exact, and nonzero, in the limit as the strength of interaction is appropriately scaled to zero. The vacuum energy is also discussed.

Effective action for composite operators*John M. Cornwall[†]*Department of Physics, University of California, Los Angeles, California 90024*

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An effective action and potential for composite operators is obtained. The formalism is used to analyze, by variational techniques, dynamical symmetry breaking and coherent solutions to field theory. A Rayleigh-Ritz procedure is introduced which replaces arbitrary variations with parametric variations. Previously unsolved nonlinear equations become, in the Rayleigh-Ritz approximation, solvable algebraic equations.