

**Veneziano G.** Construction of a crossing-symmetric, Regge-behaved amplitude for linearly rising trajectories. *Nuovo Cimento A* 57:190-7, 1968.  
[CERN, Geneva, Switzerland]

This paper is usually regarded as the one that started a new type of quantum relativistic theory, the "dual resonance model," whose fundamental objects are one-dimensional strings rather than point-like particles. After the initial excitement at the end of the 1960s and a long period of oblivion, these theories are now very fashionable again, offering hope for an overall unification of all particles and forces. [The *SC*<sup>®</sup> indicates that this paper has been cited in over 945 publications since 1968.]

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By the mid-1960s, the theory of strong interactions (those responsible for binding nucleons together in a nucleus) was in poor shape. Standard field theoretical schemes of the QED type looked far too inadequate for describing the complex-level structure of strong interacting particles (hadrons). The S-matrix "bootstrap" approach of G.F. Chew, on the other hand, was too general, and hence not really predictive.

Developments, finding their origin in the so-called Current Algebra of M. Gell-Mann, led S. Fubini and coworkers<sup>1</sup> to derive a set of constraints known as "superconvergence" (and later generalized to the so-called "finite energy sum rules") for strong interactions. Dolen, Horn, and Schmid<sup>2</sup> provided another fundamental idea which they named "duality," stating that strong interactions are generally dominated by the exchange of single resonances.

The nice and simple outcome of some work done in collaboration with M. Ademollo,

lo, H.R. Rubinstein, and M.A. Virasoro,<sup>3</sup> aiming at imposing superconvergence and duality at the same time, led me to believe that a closed-form solution to all these constraints might exist.

The first hints of its possible form came to my mind around May-June 1968 before leaving Israel for Europe, the actual conception taking place on the boat trip from Haifa to Venice. The results were fully worked out and polished at CERN, Geneva, where they appeared in preprint form in July 1968. At the International Vienna Conference in August 1968, this was already hailed as a sort of breakthrough by the scientific community.

If the existence of a simple closed form was already surprising, the developments that followed in the subject of dual resonance models in the years 1968-1972 came as a miracle, going far beyond any expectation in terms of elegance and consistency. Eventually, these nice features were understood as due to a relativistic quantum string underlying the original model. All these developments certainly explain the numerous quotations of the original article.

In spite of its beauty, the dual (string) theory was abandoned around 1973-1974 as a fundamental theory of strong interactions and was replaced on phenomenological grounds by a local field theory, "quantum chromodynamics," in which hadrons, rather than elementary, are bound states of permanently confined quarks and gluons.

But dual models may not yet have said their last word. Since 1984, the scientific community, thanks to some stunning developments in string theory by M.B. Green and J.H. Schwarz,<sup>4</sup> is again excited about dual models. People now take seriously an earlier proposal by J. Scherk and Schwarz<sup>5</sup> in which an appropriate dual string theory having supersymmetry (the "superstring") might be able to describe and unify all known fundamental particles (quarks, leptons, etc.) and forces (including quantum gravity). According to E. Witten, who has contributed much to this resurrection of the dual strings, the latter are likely to dominate high-energy theoretical physics for the first half of the next century!

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2. Dolen R, Horn D & Schmid C. Finite-energy sum rules and their application to  $\pi N$  charge exchange. *Phys. Rev.* 166:1768-81, 1968. (Cited 545 times.)
3. Ademollo M, Rubinstein H R, Veneziano G & Virasoro M A. Bootstrap of meson trajectories for superconvergence. *Phys. Rev.* 176:1904-25, 1968.
4. Green M B & Schwarz J H. Anomaly cancellations in supersymmetric  $D=10$  gauge theory and superstring theory. *Phys. Lett. B* 149:117-22, 1984.
5. Scherk J & Schwarz J H. Dual models for non-hadrons. *Nucl. Phys. B* 81:118-44, 1974.