Veneziano Representation Excites Strong-Interaction Theorists

Over the past year a simple new expression for the scattering amplitude has excited new hope for strong-interaction theory. The Veneziano representation, named for Gabriele Veneziano of the Weizmann Institute, Rehovoth, Israel, includes explicitly for the first time several properties that a strong-interaction theory presumably must have. The representation is in a simple, closed mathematical form containing products of gamma functions, and it accommodates in a consistent fashion linear Regge trajectories that are suggested by experiment.

For several years analyticity has been the magic word in strong interactions. From Chew–Low theory to the Mandelstam representation and Regge poles, progress was made, but agreement with experiment was never better than qualitative. Figure 1 is a typical Chew–Frautschi plot showing Regge trajectories.

About two years ago Richard Dolen, David Horn and Christopher Schmid of Cal Tech introduced the duality concept. They pointed out that resonances and Regge poles are really, in some average sense, the same thing said in two different ways. One can write the scattering amplitude either as a sum of a large number of resonances or with the Regge asymptotic formula. (Regge asymptotic behavior of an amplitude means that it behaves, as the energy s tends to infinity, as $\alpha(s)^{\alpha(t)-1}$ where t is the scattering angle of the original reaction, $\alpha(s)$ and $\alpha(t)$ are linear functions of s and t.) Figure 2 shows the scattering function for π–n scattering represented both by a Regge fit and by resonances. The duality is evident.

In developing a strong-interaction theory one would like the scattering amplitude to be analytic, crossing symmetric, dual and unitary. Recently Marco Ademollo (Harvard), Hector R. Rubinstein, Gabriele Veneziano and Miguel A. Virasoro (then at the Weizmann Institute)[1] studied the process $\pi + \pi \rightarrow \pi + \omega$ by sum rules originally invented by V. De Alfaro, Sergio Fubini, G. Furlan and C. Rossetti (University of Turin). The team from Harvard and Weizmann found solutions for the form of the imaginary part of the scattering amplitude that had all the required properties except unitarity. Looking into many other reactions, they were able to predict a variety of properties, for example, masses.

The group, together with Adam Schwimmer of Weizmann, using a technique invented by Schmid to check on duality, discovered that there must be an infinity of parallel trajectories. These trajectories, called daughters, had been previously postulated by Daniel Freedman and J. M. Wang (then at the University of California, Berkeley) and M. Toller (then at the University of Rome) on analyticity grounds. That the trajectories are all parallel, however, was surprising.

Then Veneziano found a representation that summarizes the sum-rule work in a closed formula that reads

$$A\,(s,t,u) = \frac{\Gamma\,[1-\alpha(s)]\,\Gamma\,[1-\alpha(t)]}{\Gamma\,[2-\alpha(s)-\alpha(t)]} + \frac{\Gamma\,[1-\alpha(s)]\,\Gamma\,[1-\alpha(u)]}{\Gamma\,[2-\alpha(s)-\alpha(u)]} + \frac{\Gamma\,[1-\alpha(t)]\,\Gamma\,[1-\alpha(u)]}{\Gamma\,[2-\alpha(t)-\alpha(u)]}$$

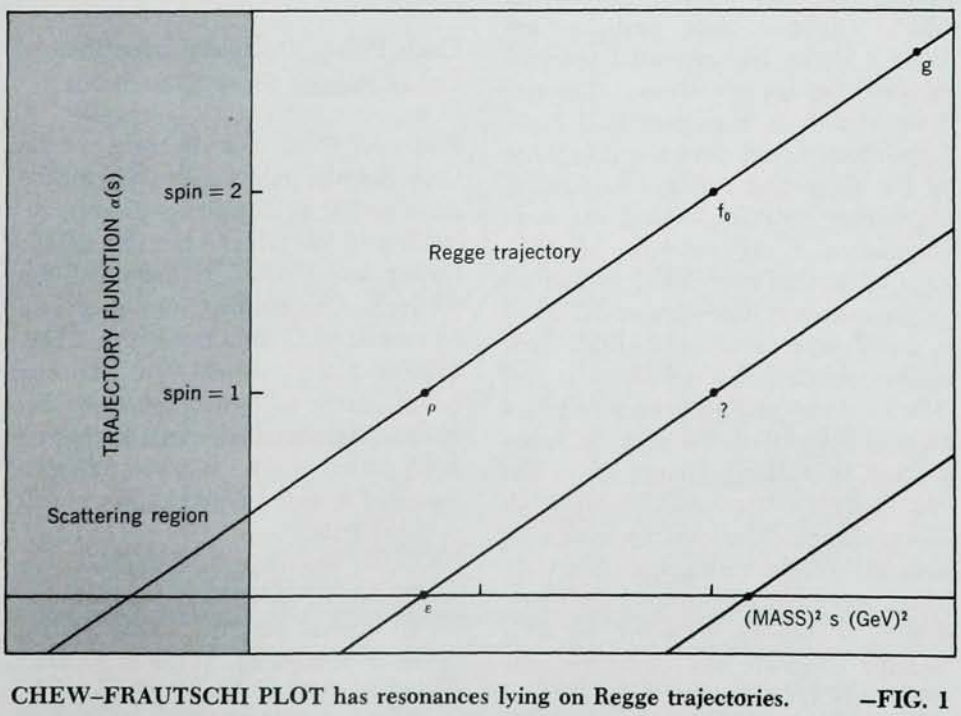
where u is a linear function of s and t, the Γ are gamma functions, $\alpha(s) = s\alpha'(0) + \alpha(0)$, etc. Because of the gamma functions the terms have poles at negative integers, and the poles correspond to particles on the trajectories. The formula has the needed analyticity and Regge behavior, in fact

$$A(s,t,u) \xrightarrow[s\rightarrow\infty]{} \alpha(s)^{\alpha(t)-1}$$

and the formula has the required properties of symmetry under s,t,u exchange, called crossing symmetry [for example $A(s,t,u) = A(t,s,u)$].

Now Virasoro,[2] Stanley Mandelstam (Berkeley),[3] Guido Altarelli (New York University) and Rubinstein[4] find an infinity of solutions to the sum rules of De Alfaro and his collaborators; this result reflects some general theorems that David Atkinson (then at Niels Bohr Institute) and K. Dietz (University of Bonn) proved on the nonuniqueness of solutions to these problems.

Now the work has been generalized to production (in which more particles leave than enter) amplitudes by Hong Mo Chan,[5] K. Bardacki and H. Ruegg (CERN)[6] and Virasoro (now at the University of Wisconsin),[7] and Claude Lovelace (CERN)[8] has found a new realm of applications in final-state interaction theory by explaining as a consequence of duality some Dalitz



CHEW–FRAUTSCHI PLOT has resonances lying on Regge trajectories. —**FIG. 1**

plots that had been mystifying.

Many theorists are working on the representation, especially attempting to make the theory unitary (as probability must be conserved). If one can add unitarity to the theory, it would mean that we live in a world composed of an infinite variety of resonances.

References

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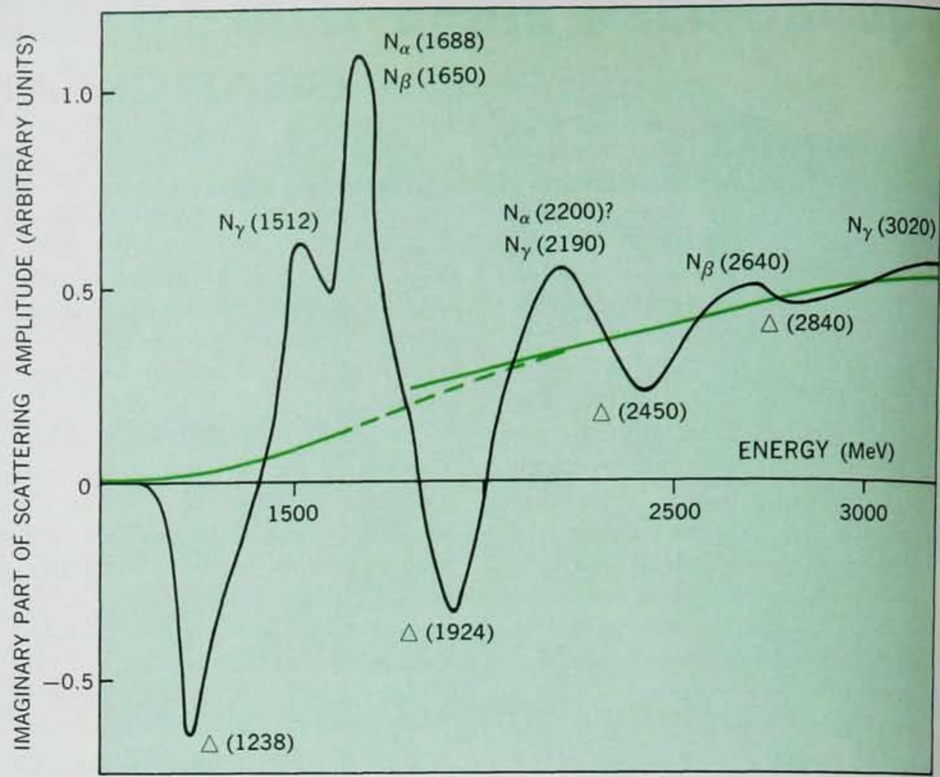

SCATTERING AMPLITUDE for π–n scattering represented by two Regge fits (color) and by resonances. One can write the scattering amplitude either as a sum of a large number of resonances or with the Regge asymptotic formula. This duality concept is a key feature of the Veneziano representation. **—FIG. 2**

Grids Instead of Walls for Electrogasdynamic Generators

A change in the design of pilot experiments at Gourdine Systems, Inc., makes the prospects for efficient generation of electricity by electrogasdynamics more promising.

The electrogasdynamic (EGD) power generator is like a Van de Graaff generator without the moving belt. Charged dust particles are carried to the high-potential terminal in a moving hot gas stream. The system is thus a high-potential, high-impedance output device, unlike those of the competing system, magnetohydronamics (MHD), which are low-impedance, high-current devices. One advantage over MHD is that no large magnet is necessary in EGD.

Early experiments with EGD generators showed that efficiency is lost when the charged particles precipitate onto the walls of the ceramic tubes instead of making their way to the high-voltage terminal. Meredith Gourdine, president of the company, and his research director, Ernst de Haas, recently demonstrated their new system. Instead of many separate parallel channels with solid ceramic walls they now use one large channel with a grid system that essentially divides the single channel into many small parallel ones. The grids define the flow path and provide "walls" of greater than 90% transparency.

The first model built in this way provides 4 watts of power at 120 000 volts. de Haas believes that industrial models will go to 500 MW at 40% efficiency, with input gas temperatures of 1000°C.

Crab Pulsar Optically Identified; Other Pulsars Show Slowdown

Pulsar NP 0532, near the center of the Crab Nebula, pulses optically with the same period as its radio emissions, according to W. John Cocke, Michael J. Disney and Donald J. Taylor of the Steward Observatory (International Astronomical Union Circular No. 2128, 1969). The University of Arizona group, using a 36-inch reflector, discovered light flashing at the apparent radio period of 0.033095 sec from the region of a well known starlike object in the nebula.

Optical variation in NP 0532 was confirmed by Malcolm MacFarlane, Brian Warner and Ed Nather, using the 82-inch telescope at the McDonald Observatory, Texas, and by Stephen P. Maran, Roger Lynds and Donald Trumbo of Kitt Peak National Observatory, using an 84-inch telescope. The Kitt Peak workers isolated the light flashes to the starlike object with a precision of better than 1 arc sec. Last spring the Kitt Peak group had found light variation from CP 1919 that had a period twice the radio period, but subsequent confirmation was later withdrawn. Unlike the weak light from CP 1919, which had to be integrated for hours, the Crab source could be seen by simply sweeping the equipment about 30 times a second for less than a minute.

The pulse shape as a function of time appears the same in both the optical and radio regions; this suggests the same mechanism that beams the radio emission also beams the optical flashes.

Slow down. NP 0532 was the first pulsar reported to be slowing down (PHYSICS TODAY, February, page 67). The rate at which its period is lengthening, 1 part in 2000 per year, implies that the lifetime of the physical characteristics that cause radio pulsations is approximately several thousand years.

Since then John G. Davies, G. C. Hunt and F. Graham Smith of Jodrell