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A DYNAMICAL APPROACH TO SUCCESSIVE ASYMPTOTIA

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A B S T R A C T

It is argued, on the basis of a multiperipheral dynamics, that the s^α expansion of amplitudes could be appropriate for not too high energies (first asymptotic expansion). At ISR energies we should witness the first steps in the building up of the second asymptotic expansion which would imply $(\log s)^\beta$ behaviour.

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I discuss in this note a non-conventional picture for high energy hadron dynamics which arises by a consistent application of the multiperipheral ideas, together with the fact that total cross-sections do not decrease at high energies ^{*)}. The multiparticle amplitude that emerges from this picture leads, naturally, to subsequent degrees of asymptotism. Our celebrated "asymptotic region" (5-100 GeV) appears as only the first step in this approach to asymptopia and is characterized by energies - s - sufficiently large so as to distinguish different powers of s . These powers are generated, in this approach, by sums over polynomials in $\log s$ and represent the shadow of inelastic events with small rapidity gaps. The next step in asymptotism are energies so large that different powers of $\log s$ are recognizable. These powers are made by sums over polynomials in $\log \log s$ and their dynamical origin is attributed to inelastic events with large rapidity gaps. It is argued that this second "asymptotic" stage is far beyond our present accelerators' reach and what one recognizes at ISR energies are the first few terms in $\log \log s$.

By recalling the origin of the multiperipheral model (m.p.m.), we first show that if the output total cross-section does not decrease with energy, the model needs - for its consistency - to be enlarged by the addition of at least the output diffraction scattering.

The m.p.m. stems ¹⁾ from the consistent application of the peripheral assumption, due to which the basic dynamical input is the low energy amplitude (let us say, in the hundred MeV-GeV region), while as soon as the energy gets higher, the bulk of the events will be represented by the production of two low energy systems connected by a small momentum transfer. The consistent application of such an idea implies that the major fraction of high energy events are given by production of low energy systems (with a spectrum decreasing with its square mass), separated by successive small transfer momenta. The smallness of the transfer momentum could be guaranteed by the exchange of a (small mass) particle or a Regge pole. Events of that type are obviously expected in any particle theory; it is the data that must tell us whether or not there is any basically high energy dynamical new feature which is not the reconnection of high energies to lower ones.

The success of the m.p.m. predictions - factorized Regge behaviour of two-body amplitudes, logarithmic multiplicity of secondaries, limitations of transverse momenta, pionization, strong scaling and short-range correlations - show that there is no compelling need for new dominant dynamical features at high energies.

^{*)} The ideas developed here are closely related to those presented - in a somewhat different language - in Ref. 1).

Could the m.p.m. be considered as a consistent picture for all high energies ? The answer could be yes if the resulting Regge trajectories, i.e., the powers of s in the overlap function generated by m.p. events (Fig. 1), turn out to be smaller than one which implies vanishing asymptotic cross-sections.

There are two reasons for that. First, there is no difficulty in considering the exchanged particles in the m.p. chain to be the output Regge poles as long as $\alpha(0) < 1$. Secondly, if cross-sections do not vanish for increasing energies, there is no justification to have neglected the direct re-interaction of final particles which are not neighbouring in the m.p. chain, i.e., with large rapidity gaps. This would ruin the m.p.m. results which are based on short-range correlations.

Now, in the 5-100 GeV region, cross-sections seem to be quite flat and satisfy reasonably well the Pomeranchuk theorem. More precisely, the Regge analysis of that "high energy" region indicates a Pomeron (call it $\mathbb{P}_0$) of intercept near one ^{*)} and non-dominant Reggeons with intercept near $\frac{1}{2}$.

The fact that notwithstanding $\alpha_{\mathbb{P}_0}(0) = 1$ data seem to agree with m.p.m. results in the 5-100 GeV region, suggests that $\mathbb{P}_0$ is perhaps not so strongly coupled. This suggestion is supported by :

- a) the anomalously small ratio of elastic to inelastic cross-sections (of the order of 1/5 for pp scattering, as compared to 1 for a black disk);
- b) the success of weak absorptive corrections to Regge analysis of two-body and quasi-two-body scattering ⁴⁾;
- c) the small triple Pomeron coupling ^{1), 5)} as measured from diffractive production of large masses which, in the m.p.m., would be represented by Fig. 2.

The $\mathbb{P}_0$ corrections, which seem to be small in the 5-100 GeV region, cannot, however, remain small at too high energy. Indeed, the total cross-section of events as those of Fig. 2 increases as $g_{\mathbb{P}_0}(0) \log \log s$, where $g_{\mathbb{P}_0}(0)$ is the triple Pomeron coupling at $t=0$ (given by the analysis of diffractive production of large masses in the limit of zero transfer momentum) and will end giving a dominant contribution.

*) In the m.p.m. $\alpha_{\mathbb{P}_0}(0)$ is related to an eigenvalue problem and the value 1 has not a privileged status. Why it is one is a stimulating puzzle towards whose solution some propositions have been recently advanced ³⁾.

In order to avoid this fact, it has been argued that $g_{\mathbb{P}_0}(0) = 0$ a value which cannot be ruled out by present experimental evidence ^{5),6)}. The dynamics which would give rise to such a vanishing is rather complicated and is surely not the multiperipheral one ⁷⁾. We recall, however, that one should not compare J plane arguments - which refer to the ultimate asymptotic amplitudes - with those we use for $\mathbb{P}_0$, which is only a first step towards asymptopia.

Likewise, the events with two and more large gaps will become important and give even larger contributions to the shadow elastic amplitude (overlap function). If these would be the only contributions, they will end by summing up to a Pomeron with intercept larger than one.

It is, however, inconsistent to single out and consider only these contributions. Indeed, as said before, $\mathbb{P}_0$ will give a re-interaction between final states with large rapidity differences. These contributions to the overlap function will be negative due to their absorptive nature.

It has been argued that absorptive corrections to a Pomeron which otherwise would be larger than one, can lead to a black disk picture which saturates unitarity ^{1),8)}.

An explicit calculation of $\mathbb{P}_0$ iteration, more consistent with our present views, has been recently attempted by Ciafaloni and Marchesini ⁹⁾. They have computed the sum of diagrams as those of Fig. 3 which imply $\mathbb{P}_0$ corrections to the one large gap events of Fig. 2. They have calculated the inclusive distribution through an integral equation whose kernel is determined by $\mathbb{P}_0$. Every contribution to the total cross-section grows as $(-\log \log s)^n$ - n being the number of exchanged $\mathbb{P}_0$ in Fig. 3 - but they sum to

$$\frac{d\sigma}{dx} = \frac{c}{(1-x)|\ln(1-x)|} \left(\frac{|\ln(1-x)|}{\ln s} \right)^\epsilon \quad (1)$$

where x is the usual scaling parameter related to the missing mass M by $M^2 = (1-x)s$ and c is a constant proportional to $g_{\mathbb{P}_0}(0)$; ϵ is determined by the solution of the eigenvalue problem; it satisfies $0 < \epsilon < 1$ and is proportional to $g_{\mathbb{P}_0}(0)$ for small $g_{\mathbb{P}_0}(0)$.

The total cross-section given by integrating the distribution of Eq. (1) does not diverge for $s \rightarrow \infty$ thanks to the $(\ln(1-x)/\ln s)^\epsilon$ factor generated by the $\mathbb{P}_0$ iterations. Indeed

$$\sigma_{tot} = \frac{c}{\varepsilon} \left(1 - \frac{1}{(\log s)^\varepsilon} \right) \quad (2)$$

The absorbed triple Pomeron contribution to the total cross-section ends therefore in a constant, that can be absorbed in a redefinition of $\mathcal{P}_0$ itself [it factorizes, by the way ⁹⁾] minus a non-dominant contribution. This calculation is only an indication of how contributions increasing as $(\log \log s)^n$ can sum up to give $(\log s)^\beta$. The fact that in this particular example the leading term has $\beta=0$ is appealing but seems to be peculiar to the triple Pomeron (one large gap events). Preliminary results ¹⁰⁾ on more complicated processes - many large rapidity gap events - seem to indicate that the leading power of $\log s$ is not zero and is, again, related to $g_{\mathcal{P}_0}(0)$.

Let us now discuss an important feature that appears naturally in the s channel language we are using. This is that the $(\log \log s)^n$ summing to $(\log s)^\beta$ is a property which is only asymptotic in $\log s$. This is due to a threshold behaviour and is similar to the one present for the Pomeron s^α behaviour, as built from fixed peripheral $(\log s)^n$ powers. To produce the $(\log \log s)$ increasing cross-sections (from the graph of Fig. 2), we needed a rather high energy, so as to have a large gap [the $\mathcal{P}_0$ which has a threshold both in the m.p.m. and in experimental data ¹¹⁾ ⁹⁾] and a multiperipheral chain. The $(\log \log s)^2$ term comes from a single re-interacting Pomeron in Fig. 3. However, to obtain the $(\log \log s)^2$ behaviour, the energy must be so large as to have a gap and to allow the reconstruction of two multiperipheral chains on both sides of the particle which rescatters with A ⁹⁾. At those energies we will have also the two large gap contribution without rescattering corrections. We see therefore that the reconstruction of the $(\log s)^\beta$ behaviour is very slow : at ISR energies we are seeing only the very first $\log \log s$ term.

The second asymptotic region $(\log s \rightarrow \infty)$ is therefore far from reach for present and future accelerator energies. To infer on its property from ISR data would be as wrong as to try to infer on the Pomeron from 500 MeV events in which the single peripheral component is only starting to emerge.

Summarizing, our m.p.m. extended so as to include $\alpha \mathcal{P}_0(0) = 1$ is the following. The input is the low energy dynamics. In the region going from the hundreds of MeV to the several GeV one, we see the peripheral terms building up of the multiperipheral events in which only small rapidity gaps

are present. This is the first asymptotic level whose shadow is the Regge pole amplitude with a Pomeron ($\mathcal{P}_0$) of intercept nearly one [or exactly one if there is some specific reason, as was recently suggested ³⁾]. This first asymptotic region, in which we can distinguish different powers of s , goes up to the hundreds GeV. At this stage, and up to ISR energies, multiparticle production processes with a large gap start appearing. To describe them, it is proper to add to the multiperipheral dynamics - with weak $\mathcal{P}_0$ absorption corrections - the diffractive production processes generated by the aforementioned $\mathcal{P}_0$. Going beyond (using our minds and, perhaps, some help from cosmic rays), we should witness the appearance of multi-gap events and their slow summing to the second asymptotic step in which we find asymptotic $(\log s)^\beta$ expansions.

Whether this is an ultimate expansion ($\beta = 2$ to saturate unitarity ?) or the game continues towards a $(\log \log s)^\gamma$ level is a completely academic question, the mass of the universe being an ultimate limit to asymptopia.

The successive high energy expansions, which have a clear meaning in energy variables are of obscure interpretation in the J plane. This perturbative treatment is invalid ¹⁾ in J and it could therefore happen that the singularities of the amplitudes in the J plane are extremely complicated.

The Regge pole expansion in the 5-100 GeV, which has a dynamical origin in this framework, is irrelevant for an ultimate asymptotic expansion of the amplitude and, therefore, irrelevant for the J plane singularities of the total amplitude.

It seems at first sight paradoxical, but we propose that the Regge pole expansion could be relevant for a limited (even if very large) energy region and not related to an asymptotic expansion of the scattering amplitude ! The decouplings ¹²⁾ and other properties obtained from a self-consistent behaviour of the amplitude would be therefore inexistant. No doubt that ultimately asymptotic amplitudes - if such a concept has any meaning - should satisfy self-consistent relations; what seems out of place - in this picture - is to associate these amplitudes with the Regge pole expansion of accelerator energies.

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R E F E R E N C E S

- 1) D. Amati, L. Caneschi and M. Ciafaloni, Nuclear Phys. B62, 173 (1973).
- 2) D. Amati, S. Fubini and A. Stanghellini, Nuovo Cimento 26, 896 (1962).
- 3) G. Veneziano, Phys.Letters 43B, 413 (1973) and private communication;
Huan Lee, Phys.Rev.Letters 30, 719 (1973).
- 4) C. Michael, Proceedings of the XVIth International Conference on High
Energy Physics, Batavia, Vol.3, p. 165 (1972).
- 5) G.C. Fox, CALT-68-413, Table 5, (1973).
- 6) Cf., L. Foà, Proceedings of the 2nd Aix-en-Provence International
Conference on Elementary Particles, p. 317 (1973).
- 7) J.B. Bronzan, Phys.Rev. D7, 480 (1973);
J. Cardy and A. White, CERN preprint TH.1740 (1973).
- 8) J. Finkelstein, preprint CO-2271-17 (1973);
F. Zachariasen, Proceedings of the 2nd Aix-en-Provence International
Conference on Elementary Particles, p. 379 (1973).
- 9) M. Ciafaloni and G. Marchesini, CERN preprint TH.1776 (1973).
- 10) M. Ciafaloni, private communication.
- 11) H. Harari, Lectures at Scottish Universities Summer School of Physics,
Ref. W15 73/32Ph, p. 16. (1973).
- 12) Cf., for instance, F. Low, Proceedings of XVIth International Conference
on High Energy Physics, Batavia, Vol.3, p. 459 (1972).

fig. 1

fig. 2

fig. 3