SATURATION AND DIFFRACTIVE DIS

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DIFRACTIVE DIS

\[ W^2 \gg Q^2, H^2, |t| \]

- **4 DIMITIONFUL SCALES**
  - Hard scale
  - Soft scale

- **REGGE LIMIT**

- **DIMENSIONLESS RATIOS**
  
  \[ X = \frac{Q^2}{W^2} \]
  
  Bj variable \( \ll 1 \)

  \[ X_P = \frac{Q^2 + H^2}{W^2} \]
  
  Proton mom. fraction transferred into diff. system \( \ll 1 \)

  \[ \beta = \frac{X}{X_P} = \frac{Q^2}{Q^2 + N^2} \]
  
  Bj variable for diffractive system
DIFFRACTIVE STRUCTURE FUNCTION

\[ \frac{d^3O}{dx蒲 dx dQ^2} = \frac{4\pi m^2}{x Q^4} (1-y + \frac{t}{x}) \cdot F_2^D(x, x蒲, Q^2, t) \]

HERA: \( F_2^D \) depends logarithmically on \( Q^2 \)
for fixed \( \beta = \frac{x}{x蒲} \)

DIFFRACTIVE PARTON DISTRIBUTIONS

\[ F_2^D = \sum \epsilon_t^2 \beta \left\{ q_t^0(\beta, Q^2, x蒲, t) + \bar{q}_t^0(...) \right\} \]

\( \beta \) - Bj variable

\( Q^2 \) - evolution variable \( (DGLAP = \text{eq. eqs}) \)

\( t, x蒲 \) - parameters for evolution

PROBLEM: TO MODEL \( t, x蒲 \) DEPENDENCE

\( \beta \)-form from QCD fits to data
**INGELMANN - SCHLEIN MODEL**

\[ F_2^D = f(x_F, t) \cdot 2 \sum_i e_i^2 \beta \left\{ q_i^D(\beta, Q^2) \right\} \]

**POMERON FLUX**

\[ = B^2(t) x_F^{1-2 \alpha'_P(t)} \]

**Regge trajectory**

\[ \alpha'_P(t) = \alpha'_P(0) + \alpha'_t \cdot t \]

**IN THIS MODEL:** REGGE FACTORIZATION OF DIFFRACTIVE PD

\[ q_i^D(\beta, Q^2, x_F, t) = f(x_F, t) \cdot q_i^D(\beta, Q^2) \]
WHAT IS $\mathcal{P}$ IN QCD?

- Two gluon exchange - no energy dependence
- BFKL ladder
- Many gluon exchanges . . .

\[ \frac{d\sigma}{dt} \bigg|_{t=0} = \int d^2r \, dz \, |\Psi(r, z, Q)|^2 \, d^2(n, x) \]

\[ \sigma^{\text{inc}} = \int d^2r \, dz \, |\Psi(r, z, Q)|^2 \, \hat{\sigma}(r, x) \]

\[ \hat{\sigma}(r, x) - \text{dipole cross section} \]

\[ F_2 \sim Q^2 \, \sigma^{\text{inc}, 0} \]
Saturated and Diffraction

Model of Dipole Cross Section:
\[ \hat{\sigma}(t,x) = \sigma_0 \left( 1 - e^{-x^2 Q_s^2(x)} \right) \]

\[ Q_s(x) \sim x^{-2}, \quad x \approx 0.15 \]

Saturation Scale

- **Diffraction Probes Directly Saturation Region!**
- **Ratio:**

\[ \frac{\hat{\sigma}_D}{\hat{\sigma}_{MC}} \sim \frac{A}{\ln \frac{Q_s^2(x)}{Q^2}} \]

Depends Logarithmically on \( x \) (Energy)!
$\sigma_{\text{diff}} / \sigma_{\text{tot}}$ ratio and ZEUS 94 data

$Q^2 = 8 \text{ GeV}^2$  
$Q^2 = 14 \text{ GeV}^2$  
$Q^2 = 27 \text{ GeV}^2$  
$Q^2 = 60 \text{ GeV}^2$

$M_X < 3 \text{ GeV}$

$3 < M_X < 7.5 \text{ GeV}$

$7.5 < M_X < 15 \text{ GeV}$

$W(\text{GeV})$
Saturation model in diffraction

Diffractive state is formed by $qq$ and $qqg = gg$ dipoles.

Interaction with the proton given by the found dipole cross section $\hat{\sigma}(r/R_0(x))$. $(R_0 = 1/Q_s)$

The diffractive structure function

$$F_2^D(\beta, Q^2, x_P) = F_{qq}^T + F_{QQ}^L + F_{qgg}^T$$

$$F^D \sim \frac{Q^4}{x} \frac{d\sigma^D}{dM^2}$$
ZEUS 94 data at $x_F = 0.0042$

$F_2(d^2)$ vs $Q^2$ for different values of $Q^2$:
- $Q^2 = 8$ GeV$^2$
- $Q^2 = 14$ GeV$^2$
- $Q^2 = 27$ GeV$^2$
- $Q^2 = 60$ GeV$^2$

$qqg$, $Tqq$, $Lqq$

$F_{qar{q}}^L$ is higher twist $\sim 1/Q^2$.

$\beta = \frac{Q^2}{Q^2 + \alpha^2}$
\[ x_{Ep} \text{-dependence - comparison with H1 data} \]
$x_p$-dependence - comparison with ZEUS data

$x_p F_2 \sim (\beta, Q^2, x_p)^{\frac{D(c)}{2}} \sim x_p^{-2}$

fixed
**Diffraction PDF from saturation model**

\[ F_2^D = F_q^{Tq} + F_q^{Lq} + F_{qg}^{Tqg} \]

1. From \( F_{qg}^{Tq} \) quark DPD → \( q^D (\beta, x_P) \)
2. From \( F_{qg}^{Tq} \) gluon DPD → \( g^D (\beta, x_P) \)
3. \( F_{qg}^{Lq} \) higher twist \( \sim 1/Q^2 \)

**Result:**

\[ q^D, g^D \text{ have Regge factorization property} \]

\[ \begin{align*}
  x q^D (\beta, x_P) &\sim Q^2(x_P) \cdot h_q (\beta) \sim x_P^{-0.29} \\
  x g^D (\beta, x_P) &\sim Q^2(x_P) \cdot h_g (\beta) \sim x_P^{-0.29}
\end{align*} \]

Which leads to measured effective \( T^P \) intercept

\[ F_2^D \sim x_P^{1 - 2 x_P \omega^R} \]

DGLAP evolution does not affect \( \omega^R \).
Diffractive $p d$ at $Q^2_0 = 1.5$ GeV$^2$
and $x_P = 0.003$
DIFRACTIVE VECTOR MESON PRODUCTION

1. DIPOLE CROSS SECTION:

\[ \hat{\sigma}^D(t, x) = 2 \int d^2b \ N(n, b, x) \]

\[ \downarrow \]

dipole scattering amplitude

\[ \gamma^* \rightarrow q\bar{q} \rightarrow V \]

2. IN VM PRODUCTION

\[ \frac{d\sigma^{VM}}{dt} = \left| \psi^* \otimes \int d^2b \ e^{i\hat{b} \cdot \hat{A}} N(r, b, x) \otimes \psi \right|^2 \]

WHERE

\[ t = -\Delta^2 \]

FROM t-dependence of \( \frac{d\sigma^{VM}}{dt} \) TO b-dependence of scattering amplitude.
EXCLUSIVE $\rho^0$ MESON IN $\gamma^* p$

$t$ dependence of $\sigma(\gamma^* p \rightarrow \rho^0 p)$ and $\alpha_p(t)$

⇒ For $\rho^0$ $b$ decreases with $Q^2$

⇒ Possibly small shrinkage
SUMMARY

1. DIPOLE CROSS SECTION WITH SATURATION APPLIED TO INCLUSIVE DIFFRACTION IN DIS DESCRIBES:
   - ENERGY DEPENDENCE ($x_F$)
   - CONSTANT RATIO $\sigma_0 / \sigma_{inc}$

2. IN LEADING TWIST DESCRIPTION, DIFFR. PARTON DISTR. HAVE REGGE FACTORIZATION $\Rightarrow$ MOTIVATION FOR INGELMANN SCHLEIN MODEL

3. DIFFRACTIVE VM PRODUCTION PROVIDES ACCESS TO STUDY OF $b$-DEPENDENCE OF DIPOLE SCATTERING AMPLITUDE

HOPE: CONSISTENT PICTURE OF INCLUSIVE AND DIFFRACTIVE PROCESSES IN DIS EMERGES.