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# THEORETICAL PARTICLE PHYSICS

## University of California, San Diego

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# [1] RESEARCH PROGRAM

## A. QUANTUM CHROMODYNAMICS

### 1. HEAVY QUARK PHYSICS

(Elizabeth Jenkins, Michael Luke, Aneesh Manohar, Martin Savage)

A. Manohar and M.B. Wise studied the existence of exotic $QQ\bar{q}\bar{q}$ bound states in the heavy quark limit. It has been known from the work of Heller that such states should be bound in the limit that $m_Q \rightarrow \infty$. For finite $m_Q$ the problem is more complicated. For $Q = b$, the exotic state can be thought of as a $B - \bar{B}$ molecule. The long-range part of the potential is dominated by one-pion exchange, and is calculable. This was combined with a variational calculation to study the binding energy. Whether the $B$ meson molecule is bound depends on the strength of the $BB^*\pi$ coupling, which has not been measured. For realistic values of the coupling, it appears that the state is weakly bound. The $D - \bar{D}$ molecule is unbound.

Z. Guralnik and A. Manohar proved rigorous QCD mass inequalities for the $\bar{\Lambda}$ parameter of the heavy quark theory. The method used is an extension of the results of Weingarten to the heavy quark case. It was shown that $\bar{\Lambda} \geq 237$ MeV for mesons, and $\bar{\Lambda} \geq 637$ MeV for baryons. The inequalities are useful for analyzing the $1/m$ corrections in the heavy quark theory. They can also be used to provide rigorous upper bounds on the mass of the c- and b-quarks.

A. Manohar and M.B. Wise computed the $1/m^2$ corrections to the semileptonic decay distributions for inclusive $B$ and $\Lambda_b$ decays. The corrections are comparable in magnitude to the order $\alpha_s$ corrections to the parton model that have previously been computed. An important point of the analysis is that the lepton energy spectrum depends on the heavy quark mass, rather than the heavy hadron mass, even at order $1/m^2$.

A. Falk, M. Savage, M. Wise and M. Luke studied the fragmentation of a heavy quark to a quark-antiquark bound state. This process is computable in perturbation theory, allowing them to predict the net polarisation of $J/\psi$'s produced from $c$ quark fragmentation. They found the polarisation to be very small. They also used the same techniques to calculate the production cross section of baryons containing two heavy quarks via the fragmentation of a single heavy quark. They further were able to compute the fragmentation to baryons containing two heavy quarks by treating the two-heavy quark system as a diquark system, which is exact in the limits that both masses become infinite. Sizable branching fraction were found.

## 2. CHIRAL PERTURBATION THEORY

(Elizabeth Jenkins, Michael Luke, Aneesh Manohar, Martin Savage)

Jenkins, Luke, Manohar and Savage studied weak radiative hyperon decays and baryon magnetic moments in chiral perturbation theory. New relations amongst the magnetic moments, which are valid when non-analytic in $m_q$ corrections are taken into account, were derived and shown to be better satisfied than the Coleman-Glashow $SU(3)$ symmetry relations.

Jenkins computed $SU(3)$ and hyperfine mass splittings of mesons containing a single heavy quark to one-loop order in chiral perturbation theory with heavy quark spin symmetry. Electromagnetic contributions of order $\alpha_{em}$ were included in the analysis.

Savage has also continued to work on soft hadronic physics and has been interested in radiative and electrostatic properties of the baryon decuplet. M. Butler, R. Springer and Savage showed that the leading contribution to the $E2$ component in the radiative decay $\Delta \to N\gamma$ was computable in chiral perturbation theory and was much larger than estimated in various hadronic models. For similar reasons they could compute the quadrupole moments of these baryons.

## 3. SKYRMIONS

(Elizabeth Jenkins, Michael Luke, Aneesh Manohar)

Jenkins, Manohar and Wise constructed a soliton model of baryons containing a single heavy quark, in which the heavy quark baryon is treated as a bound state of a heavy quark meson and an $SU(2)$ Skyrmion. The unique single derivative interaction of the heavy meson-pion Lagrangian produces bound states with the correct quantum numbers for identification with the $\Lambda_Q$, $\Sigma_Q$ and $\Sigma_Q^*$ baryons.

Guralnik, Luke and Manohar showed that properties of the heavy quark baryons are calculable in this model in terms of properties of the $N$ and $\Delta$ solitons and the $D$ and $D^*$ mesons. A number of simple results obtained at leading order in the $1/N_c$ and $1/m_Q$ were found to be in good agreement with experiment.

Jenkins and Manohar calculated the hyperfine mass splittings of the heavy quark baryons of the Skyrme model in the large $N_c$ limit, and showed that the quark model also produces the same large $N_c$ behavior for these splittings.

## 4. LARGE-N LIMIT

(R. Dashen, Elizabeth Jenkins, Aneesh Manohar)

R. Dashen and A. Manohar computed the values of the pion-baryon coupling constants in the large-N limit, by requiring that the scattering amplitude not violate unitarity. The ratios of pion couplings in the large $N_c$ limit were shown to be identical to that obtained in the Skyrme model or in the quark model. Large $N_c$ consistency conditions on other static properties such as the magnetic moments was also derived. The large-N pion couplings are such that chiral loop effects are suppressed by $1/N_c^2$. This explains the cancellation in chiral loops found previously by Jenkins and Manohar. Dashen and Manohar also proved that the $1/N_c$ correction to the pion-baryon couplings vanishes, so that the first deviation from the large $N_c$ value is at order $1/N_c^2$. This is being investigated further.

Jenkins showed that the pion couplings of heavy quark baryons are determined by a single coupling constant in large $N_c$ QCD. The pion couplings satisfy light quark spin-flavor symmetry relations to order $1/N_c^2$, in analogy to the situation for baryons containing no heavy quarks. Further, the pion coupling constant for heavy quark baryons is equal to the pion coupling constant for ordinary baryons $+\mathcal{O}(1/N_c)$. Jenkins proved that the hyperfine mass splittings of baryons are proportional to $\mathbf{J}^2/N_c$ in large $N_c$ QCD. The heavy quark symmetry violating hyperfine splittings of heavy quark baryons, such as $\Sigma_Q^* - \Sigma_Q$, are proportional to $\mathbf{J} \cdot S_Q/N_c m_Q$ in leading order in large $N_c$ QCD, where $\mathbf{J}$ is the spin of the light degrees of freedom of the heavy quark baryon.

Jenkins, Manohar and Wise computed the Isgur-Wise function for $\Lambda_b \rightarrow \Lambda_c$ semileptonic decay in the large $N_c$ limit. Heavy quark symmetry-breaking $1/m_Q$ corrections to the Isgur-Wise function of the form $m_N/m_Q$ were summed exactly. This correction changed the normalization of the Isgur-Wise function at zero recoil by only 1%, which suggsts that Luke's theorem may be very accurate for this form factor.

# B. ELECTROWEAK INTERACTIONS

## 1. WEAK SCALE BARYOGENESIS

(Ann Nelson and David Kaplan)

Ann Nelson, with Andy Cohen from Boston University, analyzed the constraints on the minimal supersymmetric standard mdoel which would arise from the cosmological requirement of weak scale baryogenesis. They found that baryogenesis is possible in this model, provided that the top squark is lighter than 150 GeV, tan $\beta$ is smaller than 1.5, the lightest chargino and neutralino are not too heavy, and the new CP violating phases are large enough so that the neutron electric dipole moment is larger than $10^{-27}$ e-cm. Cohen, David Kaplan and Nelson wrote an invited review on weak scale Baryogenesis.

## 2. SUPERSYMMETRY

(Ann Nelson and David Kaplan)

With Michael Dine (at UCSC) Nelson demonstrated that it is possible to have phenomenologically viable model of dynamical supersymmetry breaking in the visible sector. The model solves several notorious problems, such as the gauge hierarchy problem and the flavor problem. In this model the weak scale naturally is exponentially small compared to the Planck scale, and squarks and sleptons are naturally degenerate because supersymmetry breaking is communicated via ordinary gauge interactions, and the gauge sector of the theory automatically has an accidental flavor symmetry.

Kaplan and Nelson, with Tom Banks at Rutgers University, discussed the cosmology of various classes of dynamical supersymmetry breaking models, and showed that in superstring inspired models, where supersymmetry breaking is driven by moduli fields in a "hidden" sector, there are always scalars with weak scale masses and gravitational strength interactions, which will be overproduced in the early universe, and dominate its energy density until the temperature is below 10 keV, making cosmological nucleosynthesis difficult to achieve.

With Nathan Seiberg at Rutgers University, Nelson has shown that in many models a spontaneously broken exact continuous R symmetry is a necessary and sufficient condition for spontaneous supersymmetry breaking. They discuss the problems associated with the resulting Goldstone boson, and find several ways of explicitly breaking the R symmetry which will not result in supersymmetry restoration.

Nelson and Lisa Randall from MIT have shown that in natural supersymmetric models, explaining the hierarchy between the top and bottom masses via large tan $\beta$ requires enlarging the Higgs sector beyond two doublets, and discuss the implications.

David Kaplan and student Martin Schmaltz are currently working on a class of Supersymmetric GUTs which explain the hierarchy in quark and lepton masses in terms of nonabelian discrete flavor symmetries. These symmetries allow one to implement "flavor democracy", i.e, enforce that all flavors of particles have identical short distance interactions, while still having a hierarchical mass structure at low energy. The mass structure comes from spontaneous breaking of the nonabelian flavor symmetry; due to vacuum alignment, the light particles only aquire mass at high powers in the symmetry breaking scale. The structure of nonabelian discrete symmetries can be very rich, giving rise to a realistic hierarchy of masses and mixing angles.

## 3. RARE DECAYS

(Michael Luke and Martin Savage)

M. Savage and M. Luke studied the effects of new scalar particles, with masses on the order of a few hundred GeV and with flavour changing couplings to fermions proportional to the fermion masses, on rare top decays. They calculated the rates for the rare top decays $t \to c\gamma$ and $t \to cZ^0$ as a function of the unknown couplings and masses of the scalars. They found that, for reasonable anzatses for the couplings, these decays are unlikely to be observable at the SSC. Recent developments in inclusive decays of B and D mesons in the context of heavy quark effective theory enabled M. Luke, A. Falk and M. Savage to compute the leading nonperturbative corrections to the parton model for the rare decays $b \to s\gamma$ and $b \to sl^+l^-$. M. Luke and M. Savage used these same techniques to extract the weak mixing angle $V_{bc}$ from inclusive semileptonic meson decays.

There has been some recent interest in the application of heavy quark techniques to the inclusive decays of hadrons containing a single b or c quark. A. Falk, M. Savage and M. Luke used these techniques to study the nonperturbative corrections to the free quark decay model for the rare decays $B \to s\gamma$ and $B \to se^+e^-$. They found the corrections to be small, of the order of a few percent. In addition, Savage and Luke used existing data on $B$ and $D$ meson semileptonic decay rates to extract the c and b quark masses, as well as the weak mixing angle $V_{bc}$. They found their extraction of $V_{bc}$ to be competitive with that obtained from studying exclusive decays.

## 4. TECHNICOLOR

(Michael Luke)

R. S. Chivukula, A. Cohen and M. Luke studied the interactions of exotic heavy coloured "technibaryons" with ordinary matter. Contrary to some previous claims in the literature, they found that the interaction cross section is so small that if such particles made up the unseen dark matter in the universe they would not be visible with present-day detectors.

# C. LATTICE FIELD THEORY

## 1. CHIRAL LATTICE FERMIONS

(Karl Jansen, David Kaplan, J. Vink)

David Kaplan continued research into the possibility of putting chiral fermions on the lattice, by means of introducing a domain wall mass defect in one higher dimension. In unpublished work he concluded that the method will not work for dynamical gauge fields on a finite sized lattice, due to edge states that exist at the boundary of the box and fail to decouple from the chiral fermions bound to the domain wall. He is presently considering a promising proposal by Neuberger and Narayanan to keep the system strictly infinite in the extra dimension, and work in a Hamiltonian formalism. In particular, he is trying to see if the proposal can be related to the work by Alvarez-Gaume et al. on expressing the phase of the chiral fermion determinant as the $\eta$-invariant.

Karl Jansen continued his work to investigate a recent proposal by Kaplan to construct chiral gauge theories on the lattice using domain wall fermions. K. Jansen, M.F.L. Golterman, D.N. Petcher and J.C. Vink did a study in a finite volume, in which two domain walls are present, with modes of opposite chirality on each of them. The chiral fermions are coupled on only one of the domain walls to a gauge field. Extending the original proposal to the case where gauge fields are included and in order to preserve gauge invariance, a scalar field was added, which gives rise to additional light mirror fermion and scalar modes. It was argued that in an anomaly free model these extra modes would decouple if the model possesses a so-called strong coupling symmetric phase. However, the numerical results the authors obtained in combination with analytical arguments strongly suggests that such a phase most probably does not exist.

The same collaborators have investigated an approach to put chiral gauge theories on the lattice, using staggered fermions. They tested this method successfully, by computing the anomaly in the presence of classical background gauge fields. They also investigated if the gauge symmetry which is broken by the staggered fermions gets restored dynamically in the quantum theory. In a simple version of their approach this was found not to be the case.

## 2. PAULI-VILLARS REGULATOR AND THE HIGGS MASS BOUND

(Karl Jansen and Julius Kuti)

Karl Jansen, Julius Kuti, and graduate student Chuan Liu continued their investigation of the Higgs mass problem. A higher derivative term was introduced in the kinetic energy of the Higgs iagrangian in the minimal Standard Model. A logically consistent and finite field theory was obtained when some excitations of the Higgs field were quantized with indefinite metric in the Hilbert space. The Landau ghost phenomenon of the conventional triviality problem was replaced by the state vectors of a complex ghost pair at a finite mass scale with observable physical consequences. It was shown that the ghost states exhibit unusual resonance properties and correspond to a complex conjugate pair of Pauli-Villars regulator masses in the euclidean path integral formulation of the theory. An argument was given that microscopic acausality effects associated with the ghost pair remain undetectable in scattering processes with realistic wave packets, and the S-matrix should exhibit unitarity in the observable sector of the Hilbert space.

The triviality Higgs mass bound was studied with the same higher derivative regulator in the spontaneously broken phase of the four dimensional O(4) symmetric scalar field theory with quartic self-interaction. The phase diagram of the O(4) model was determined in a Monte Carlo simulation which interpolates between the hypercubic lattice regulator and the higher derivative regulator in continuum space-time. The same method can be used to calculate the Higgs mass bound in continuum space-time. In a large-N analysis, when compared with a hypercubic lattice, Jansen, Kuti, and Liu found a relative increase in the triviality bound of the higher derivative regulator suggesting a strongly interacting Higgs sector in the TeV region with negligible dependence on regulator parameters. When the higher derivative regulator mass is brought close to the Higgs mass the model requires a more elaborate analysis of complex ghost states in scattering amplitudes. The latest simulation results exceed the large-N expectations and are very surprising: a 2 TeV heavy Higgs resonance in the presence of a 4 TeV heavy ghost state leads to an SSC scenario where the strongly interacting Higgs sector is realized in a consistent field theoretic description. The new results require further careful analysis before final conclusions.

## 3. HIGGS AND YUKAWA INTERACTIONS

(Jeroen Vink)

Together with W. Bock and J. Smit of the University of Amsterdam, J. Vink has investigated the effect of Yukawa interactions on the upperbound of the Higgs mass. Using staggered fermions they found that the Higgs mass bound increased by $\approx 30\%$ at the maximally allowed value of the renormalized Yukawa coupling.

## 4. GAUGE FIXING

(Jeroen Vink)

Yet another approach to chiral gauge theories on the lattice uses gauge fixing at the heart of its definition. Vink has modified this idea such that, even though the lattice actions always are evaluated in a fixed gauge, these models can be simulated without gauge fixing and Fadeev-Popov ghosts with a hybrid Monte Carlo algorithm.

# D. MISCELLANEOUS

## 1. QUANTUM BEABLES

(Jeroen Vink)

Unlike usually believed, quantum mechanics allows for a "realistic" interpretation, in terms of classical concepts such as position and momentum of a particle. Vink has shown that such a "beable" interpretation of quantum mechnics can also be given for observables with discrete values, like spin and for non-commuting observables simultaneously. This elaborated on earlier work by Bohm and Bell.

# [2] CONTRACT PUBLICATIONS

Contract publications are listed for the time period of the last twelve months:

1. A.V. Manohar, M.B. Wise, Exotic $QQ\bar{q}\bar{q}$ States in QCD, Nucl. Phys. B399 (1993) 17-33.
2. Z. Guralnik, A.V. Manohar, QCD Mass Inequalities in the Heavy Quark Limit, Phys. Lett. B302 (1993) 103-107.
3. A.V. Manohar, M.B. Wise, Inclusive Semileptonic $B$ and Polarized $\Lambda_b$ Decays from QCD, Preprint, UCSD/PTH 93-14, submitted to Phys. Rev. D.
4. A.F. Falk, M. Luke, M.J. Savage and M.B. Wise, Heavy Quark Fragmentation to Polarised Quarkonium, Phys. Lett. B312, (1993) 486.
5. A.F. Falk, M. Luke, M.J. Savage and M.B. Wise, Heavy Quark Fragmentation to Baryons Containing Two Heavy Quarks, to appear in Phys. Letts. B.
6. A.F. Falk, M. Luke and M.B. Wise, Analyticity and the Isgur-Wise Function, Phys. Lett. 299, (1993) 123-126.
7. M. Luke and M.J. Savage, Extracting $|V_{bc}|$, $m_c$, $m_b$ and $\overline{\Lambda}$ from Inclusive $D$ and $B$ Decays, to appear in Phys. Letts. B.
8. E. Jenkins, M. Luke, A.V. Manohar and M.J. Savage, Weak Radiative Hyperon Decays in Chiral Perturbation Theory, Nucl. Phys. B397 (1993) 84-104.
9. E. Jenkins, M. Luke, A.V. Manohar and M.J. Savage, Chiral Perturbation Theory Analysis of the Baryon Magnetic Moments, Phys. Lett. B302 (1993) 482-490.
10. E. Jenkins, Heavy Meson Masses in Chiral Perturbation Theory With Heavy Quark Symmetry, CERN-TH.6765/92, accepted for publication Nucl. Phys. B.
11. E. Jenkins, Recent Results in Chiral Perturbation Theory for Mesons Containing a Single Heavy Quark, XXVIIIth Rencontres de Moriond, QCD and High Energy Hadronic Interactions, ed. J. Tran Thanh Van, 1993.
12. A.V. Manohar, Chiral Perturbation Theory, Preprint, UCSD/PTH 93-12.
13. J.F. Amundson, C.G. Boyd, J.L. Rosner, M. Luke, A.V. Manohar, M.J. Savage and M.B. Wise, Radiative $D^*$ Meson Decay Using Heavy Quark and Chiral Symmetry, Phys. Lett. B296, (1992) 415.

14. M.N. Butler, M.J. Savage and R.P. Springer, Strong and Electromagnetic Decays of the Baryon Decuplet, Nuc. Phys. B399, 69 (1993).

15. M.N. Butler, M.J. Savage and R.P. Springer, E2/M1 Mixing Ratio of $\Delta \rightarrow N\gamma$ and Hyperon Resonance Radiative Decay, Phys. Lett. B304, (1993) 353.

16. M.N. Butler, M.J. Savage and R.P. Springer, Probing Hadronic Structure with $\Delta \rightarrow N l^+ l^-$, Phys. Rev. C48, (1993) 917.

17. M.N. Butler, M.J. Savage and R.P Springer, Electrostatic Properties of the Baryon Decuplet, submitted to Phys. Rev. D.

18. E. Jenkins, A.V. Manohar and M.B. Wise, Baryons Containing a Heavy Quark as Solitons, Nucl. Phys. B396 (1993) 27-37.

19. E. Jenkins and A.V. Manohar, Hyperfine Splittings of Baryons Containing a Heavy Quark in the Skyrme Model, Phys. Lett. B294 (1992) 273-280.

20. R. Dashen, A.V. Manohar, Baryon-Pion Couplings from Large $N_c$ QCD, Preprint, UCSD/PTH 93-16, to be published in Phys. Lett. B.

21. R. Dashen, A.V. Manohar, $1/N_c$ Corrections to the Baryon Axial Currents in QCD, Preprint, UCSD/PTH 93-18, to be published in Phys. Lett. B.

22. E. Jenkins, Light Quark Spin-Flavor Symmetry for Baryons Containing a Heavy Quark in Large $N$ QCD, Preprint, UCSD/PTH 93-17, accepted for publication Phys. Lett. B.

23. E. Jenkins, Baryon Hyperfine Mass Splittings in Large N QCD, Preprint, UCSD/PTH 93-19, accepted for publication Phys. Lett. B.

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26. A. G. Cohen and A. E. Nelson, Supersymmetric Baryogenesis, Phys. Lett. 297B (1992) 111.

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28. M. Dine and A. E. Nelson, Dynamical Supersymmetry Breaking at Low Energies, Phys. Rev. D48 (1993) 1277.

29. A. E. Nelson and L. Randall, Naturally Large Tan $\beta$, Preprint, UCSD/PTH 93-24, accepted for publication in Phys. Lett. B..

30. T. Banks, D. B. Kaplan and A. E. Nelson, Cosmological Implications of Dynamical Supersymmetry Breaking, Preprint, UCSD/PTH 93-26.

31. A. E. Nelson and N. Seiberg, R symmetry Breaking Versus Supersymmetry Breaking, Preprint, UCSD/PTH 93-27 (1993).

32. D. B. Kaplan and M. Schmaltz, Flavor Democracy and Nonabelian Discrete Symmetries, Preprint, UCSD-PTH-93-30.

33. M. Luke and M.J. Savage, Flavour Changing Neutral Currents, Weak Scale Scalars and Rare Top Decays, Phys. Lett. B307, (1993) 387.

34. A.F. Falk, M. Luke and M.J. Savage, Nonperturbative Contributions to Inclusive Rare $B$ Decays, submitted to Phys. Rev. D.

35. R.S. Chivukula, A. Cohen, M. Luke and M.J. Savage, A Comment on the Strong Interactions of Colour-Neutral Technibaryons, Phys. Lett. 298, (1993) 380-382.

36. M.F.L. Golterman, K. Jansen, D.N. Petcher and J.C. Vink, Investigation of the domain wall fermion approach to chiral gauge theories on the lattice, Preprint, UCSD/PTH 93-28.

37. W. Bock, J. Smit and J.C. Vink, Staggered Fermion Approach to Chiral Gauge Theories on the Lattice, Nucl. Phys. B (Proc. Suppl.) 30 (1993) 605-608.

38. W. Bock, J. Smit and J.C. Vink, Staggered Fermions for Chiral Gauge Theories: test on a Two-Dimensional Vector Model, Preprint, ITFA-93-13, UCSD/PTH 93-13.

39. W. Bock, J. Smit and J.C. Vink, Nongauge Fixing Approach to Chiral Gauge Theories using Staggered Fermions, Preprint, ITFA-93-18, UCSD/PTH 93-15.

40. K. Jansen, J. Kuti and C. Liu, The Triviality Higgs Mass Bound with Higher Derivative Lagrangian, Nucl.Phys.B (Proc.Suppl.) 30 (1993) 681-684.

41. K. Jansen, J. Kuti and C. Liu, The Higgs Model with a Complex Ghost Pair, Phys. Lett. B309 (1993) 119-126.

42. K. Jansen, J. Kuti and C. Liu, Strongly Interacting Higgs Sector in the Minimal Standard Model?, Phys. Lett. B 309 (1993) 127-132.

43. J.C. Vink, Gauge Invariant Lattice Actions for Chiral Gauge Theories, using Laplacian Gauge Fixing, Preprint, UCSD/PTH 93-29.

44. W. Bock, C. Frick, J. Smit and J.C. Vink, Can the Couplings in the Fermion-Higgs Sector of the Standard Model be Strong?, Nucl. Phys. B400 (1993) 309-246.

45. W. Bock, C. Frick, J. Smit and J.C. Vink, No Strong Coupling Regime in the Fermion-Higgs Sector of the Standard Model, Nucl. Phys. B (Proc. Suppl.) 30 (1993) 643-646.

46. J.C. Vink, Quantum Mechanics in Terms of Discrete Beables, Preprint, UCSD/PTH 93-3 (to be published in Phys. Rev. A).

# [3] CONFERENCE TALKS

1. A. Nelson, "Constraints on Supersymmetric Models from Baryogenesis", invited talk given at the Annual Meeting of the SSC Fellows, Nov 19-21, 1992.
2. A. Nelson, "Baryogenesis in the Minimal Supersymmetric Model", invited talk given at the Aspen Winter Conference on Particle Physics, Jan. 10-16, 1993.
3. D. Kaplan, "Chiral Fermions on the Lattice", Lattice '92 Conference, Amsterdam, Holland, September, 1992.
4. A. Manohar, "Baryon Chiral Perturbation Theory", Talk presented at Journée Particulière, Saclay/Orsay, March, 1993.
5. A. Manohar, "Introduction to Chiral Perturbation Theory", XXVIIIth Rencontres de Moriond, QCD and High Energy Hadronic Interactions, March, 1993.
6. A. Manohar, "Baryons in the $1/N$ Expansion", Aspen Center for Physics, July, 1993.
7. A. Manohar, "Baryon Chiral Perturbation Theory", Gordon Conference, Nuclear Physics, July, 1993.
8. E Jenkins, "Introduction to Heavy Quark Effective Theory", Talk presented at Journée Particuliere at Saclay/Orsay, March, 1993.
9. E Jenkins, "Recent Results in Chiral Perturbation Theory", XXVIIIth Rencontres de Moriond, QCD and High Energy Hadronic Interactions, March, 1993.
10. E Jenkins, "1/N Corrections to Baryon Masses", Talk presented at Aspen Center for Physics, July, 1993.
11. K. Jansen, "Chiral Fermions, Anomalies and Chern-Simons Currents on the Lattice", Lattice '92 Conference, Amsterdam, Holland, September, 1992.
12. J. Kuti, "The Triviality Higgs Mass Bound with Higher Derivative Lagrangian", Lattice '92 Conference, Amsterdam, Holland, September, 1992.

13. J. Kuti, "Higher Derivative Lagrangians", The Johns Hopkins Workshop in Theoretical Physics, July, 1993, Budapest.

# END

# DATE FILMED

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