

Contents

1	Heavy WIMP Effective Theory	1
1.1	Introduction	1
1.2	Universal Heavy WIMP Limit	4
1.3	Motivations for Heavy WIMP Effective Theory	7
1.4	Chapter Organization	9
2	Heavy-Particle Spacetime Symmetries and Building Blocks	13
2.1	Finite Dimensional Representations of the Lorentz Algebra	16
2.2	Effective Field Theory and the Little Group	18
2.2.1	Little Group Formalism	18
2.2.2	Field Transformation Law and Lorentz Invariance	20
2.2.3	$1/M$ Expansion and Lagrangian Constraints	22
2.3	Reparametrization Invariance and Invariant Operators	24
2.3.1	Covariant Notation	24
2.3.2	Reparametrization Invariance	26
2.3.3	Invariant Operator Method	26
2.3.4	Solution for $\Gamma(v, iD)$	27
2.4	Higher-Spin and Self-conjugate Fields	30
2.4.1	Higher Spin Representations	30
2.4.2	Self-conjugate Parity and CPT	32
2.5	NRQED Example: Lagrangian	33
2.6	NRQED Example: Relativistic Invariance	35
2.6.1	Variational Method	35
2.6.2	Invariant Operators	37
2.7	NRQED Example: One-Photon Matching	38
2.8	NRQED Example: Photon and Four-Fermion Sectors	40
2.8.1	Pure Photon Operators	40
2.8.2	Four-Fermion Operators	41
2.8.3	Field Redefinitions and Redundant Operators	43
2.8.4	Relativistic Lepton	45
2.9	Discussion	46

3	Effective Theory at the Weak-Scale	49
3.1	Singlet	50
3.1.1	Standard Model Building Blocks	50
3.1.2	Dark Matter Building Blocks	53
3.1.3	High-Energy Basis	53
3.1.4	Low-Energy Basis	55
3.2	Multiplets and Mixtures	57
3.2.1	Pure States	59
3.2.2	Higher-Order Example: Pure Triplet Scalar	61
3.2.3	Admixtures	63
3.2.4	Pure Case Limits	67
3.2.5	Relativistic Example: Singlet-Doublet Mixture	68
3.3	Onshell Renormalization Scheme	69
3.3.1	Singlet-Doublet Counterterm Lagrangian	69
3.3.2	Propagator Corrections	70
3.3.3	Renormalization Conditions	72
3.3.4	Extension to Triplet-Doublet	73
3.4	Low Energy Theory at the Weak Scale for Pure- and Mixed-State WIMPs	75
4	Weak-Scale Matching	77
4.1	Singlet	78
4.1.1	Case I: $M \lesssim m_b \ll m_W$	78
4.1.2	Case II: $m_W \lesssim M$	80
4.1.3	Case III: $m_W \ll M$	81
4.2	Multiplets and Mixtures	81
4.2.1	Quark Matching: One-Boson Exchange	82
4.2.2	Gluon Matching: One-Boson Exchange	86
4.2.3	Quark Matching: Two-Boson Exchange	87
4.2.4	Gluon Matching: Two-Boson Exchange	92
4.2.5	Effective Theory Amplitudes and Infrared Regulator	112
4.2.6	Extended Higgs Sector for Pure Case	113
4.2.7	Bare Matching Coefficients	114
5	QCD Analysis and Hadronic Matrix Elements	119
5.1	Operator Renormalization	120
5.1.1	Renormalization Constants	121
5.1.2	Renormalized Matching Coefficients for Pure States	123
5.2	Renormalization Group Evolution	125
5.3	Threshold Matching and Low Energy Coefficients	127
5.3.1	Heavy Quark Threshold Matching Conditions	128
5.3.2	Low Energy Coefficients	129
5.4	Hadronic Matrix Elements	130
5.4.1	Scalar Matrix Elements	130
5.4.2	Tensor Matrix Elements	132

6 Heavy WIMP-Nucleon Scattering Cross Sections	135
6.1 Cross Section Assembly Line	136
6.2 Survey of Uncertainties	138
6.3 Cross Section Predictions and Consistency Checks	140
7 Conclusions	147
Appendix A: Solution to the Invariance Equation	151
A.1 Series Solution for Γ	151
A.2 Explicit Solution for Γ in the Spin 1/2 Theory	153
Appendix B: Integrals and Inputs for Weak Scale Matching	157
B.1 Self Energy Integrals and Standard Model Two-Point Functions	157
B.2 Box Integrals	161
B.3 Heavy Particle Integrals with Electroweak Polarization Tensor Insertion	165
B.3.1 Case of Zero Heavy Fermions	166
B.3.2 Case of One Heavy Fermion	167
B.3.3 Case of Two Heavy Fermions	170
B.4 Numerical Inputs	170
Appendix C: Inputs for Analysis of QCD Effects and Hadronic Matrix Elements	173
C.1 QCD Functions	173
References	175



<http://www.springer.com/978-3-319-25197-4>

Heavy WIMP Effective Theory
Formalism and Applications for Scattering on Nucleon
Targets

Solon, M.P.

2016, XV, 177 p. 26 illus., 12 illus. in color., Hardcover

ISBN: 978-3-319-25197-4