

Appendix A: Generators and structure constants for SU(N),
N = 2, 3, 4.

All generating matrices and structure constants are based on the normalization

$$\text{Tr}(F_i F_k) = \delta_{ik}$$

and the relations (II.3.8) and (II.3.9).

i) SU(2):

$$F_1 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \quad F_2 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}, \quad F_3 = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}.$$

$$f_{ikl} = \sqrt{2}, \quad d_{ikl} = 0, \quad i, k, l = 1, 2, 3.$$

ii) SU(3):

$$F_1 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \quad F_2 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 & -i & 0 \\ i & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix},$$

$$F_3 = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{pmatrix}, \quad F_4 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix},$$

$$F_5 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 & 0 & -i \\ 0 & 0 & 0 \\ i & 0 & 0 \end{pmatrix}, \quad F_6 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix},$$

$$F_7 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & -i \\ 0 & i & 0 \end{pmatrix}, \quad F_8 = \frac{1}{\sqrt{6}} \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -2 \end{pmatrix}.$$

$f_{ik\ell} = \sqrt{2}$		$1/\sqrt{2}$	$-1/\sqrt{2}$	$\sqrt{6}/2$
$ik\ell$	1 2 3	1 4 7	1 5 6	4 5 8
		2 4 6	3 6 7	6 7 8
		2 5 7		
		3 4 5		

$d_{ik\ell} = 2/\sqrt{6}$		$1/\sqrt{2}$	$-1/\sqrt{2}$	$-1/\sqrt{6}$	$-2/\sqrt{6}$
$ik\ell$	1 1 8	1 4 6	2 4 7	4 4 8	8 8 8
	2 2 8	1 5 7	3 6 6	5 5 8	
	3 3 8	2 5 6	3 7 7	6 6 8	
		3 4 4		7 7 8	
		3 5 5			

iii) $SU(4)$:

$$F_1 = \frac{1}{\sqrt{2}} \left(\begin{array}{cc|c} \circ & 1 & \circ \\ 1 & \circ & \circ \\ \hline \circ & & \circ \end{array} \right), \quad F_2 = \frac{1}{\sqrt{2}} \left(\begin{array}{cc|c} \circ & -i & \circ \\ i & \circ & \circ \\ \hline \circ & & \circ \end{array} \right),$$

$$F_3 = \frac{1}{\sqrt{2}} \left(\begin{array}{cc|c} 1 & \circ & \circ \\ \circ & -1 & \circ \\ \hline \circ & & \circ \end{array} \right), \quad F_4 = \frac{1}{\sqrt{2}} \left(\begin{array}{cc|c} \circ & & 1 \circ \\ \circ & & \circ \circ \\ \hline 1 & \circ & \circ \\ \circ & \circ & \circ \end{array} \right),$$

$$F_5 = \frac{1}{\sqrt{2}} \left(\begin{array}{cc|c} \circ & -i & \circ \\ \circ & \circ & \circ \\ \hline i & \circ & \circ \\ \circ & \circ & \circ \end{array} \right), \quad F_6 = \frac{1}{\sqrt{2}} \left(\begin{array}{cc|c} \circ & & \circ \circ \\ \circ & & 1 \circ \\ \hline \circ & 1 & \circ \\ \circ & \circ & \circ \end{array} \right),$$

$$F_7 = \frac{1}{\sqrt{2}} \left(\begin{array}{cc|cc} 0 & & 0 & 0 \\ & & -i & 0 \\ \hline 0 & i & & \\ 0 & 0 & & 0 \end{array} \right) ,$$

$$F_8 = \frac{1}{\sqrt{6}} \left(\begin{array}{cc|cc} 1 & 0 & & 0 \\ 0 & 1 & & \\ \hline & & -2 & 0 \\ 0 & & 0 & 0 \end{array} \right) ,$$

$$F_9 = \frac{1}{\sqrt{2}} \left(\begin{array}{cc|cc} 0 & & 0 & 1 \\ & & 0 & 0 \\ \hline 0 & 0 & & \\ 1 & 0 & & 0 \end{array} \right) ,$$

$$F_{10} = \frac{1}{\sqrt{2}} \left(\begin{array}{cc|cc} 0 & & 0 & -i \\ & & 0 & 0 \\ \hline 0 & 0 & & \\ i & 0 & & 0 \end{array} \right) ,$$

$$F_{11} = \frac{1}{\sqrt{2}} \left(\begin{array}{cc|cc} 0 & & 0 & 0 \\ & & 0 & 1 \\ \hline 0 & 0 & & \\ 0 & 1 & & 0 \end{array} \right) ,$$

$$F_{12} = \frac{1}{\sqrt{2}} \left(\begin{array}{cc|cc} 0 & & 0 & 0 \\ & & 0 & -i \\ \hline 0 & 0 & & \\ 0 & i & & 0 \end{array} \right) ,$$

$$F_{13} = \frac{1}{\sqrt{2}} \left(\begin{array}{cc|cc} 0 & & 0 & \\ & & 0 & 1 \\ \hline 0 & & 1 & 0 \\ & & 1 & 0 \end{array} \right) ,$$

$$F_{14} = \frac{1}{\sqrt{2}} \left(\begin{array}{cc|cc} 0 & & 0 & \\ & & 0 & -i \\ \hline 0 & & 0 & 0 \\ & & i & 0 \end{array} \right) ,$$

$$F_{15} = \frac{1}{2\sqrt{3}} \left(\begin{array}{cc|cc} 1 & 0 & & 0 \\ 0 & 1 & & \\ \hline 0 & & 1 & 0 \\ & & 0 & -3 \end{array} \right) .$$

The structure constants for index combinations with $1 \leq i, k, l \leq 8$ are the same as those for SU(3). Only the additional values are given below.

$f_{i,k,l} = \frac{1}{\sqrt{2}}$		$-\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{6}}$	$-\frac{2}{\sqrt{6}}$	$\frac{2}{\sqrt{3}}$
i,k,l	1, 9, 12	1, 10, 11	8, 9, 10	8, 13, 14	9, 10, 15
	2, 9, 11	3, 11, 12	8, 11, 12		11, 12, 15
	2, 10, 12	4, 10, 13			13, 14, 15
	3, 9, 10	6, 12, 13			
	4, 9, 14				
	5, 9, 13				
	5, 10, 14				
	6, 11, 14				
	7, 11, 13				
	7, 12, 14				

$d_{i,k,l} = \frac{1}{\sqrt{2}}$		$-\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{6}}$	$\frac{1}{\sqrt{3}}$	$-\frac{1}{\sqrt{3}}$	$-\frac{2}{\sqrt{6}}$	$-\frac{2}{\sqrt{3}}$
i,k,l	1, 9, 11	2, 9, 12	8, 9, 9	1, 1, 15	9, 9, 15	8, 13, 13	15, 15, 15
	1, 10, 12	3, 11, 11	8, 10, 10	2, 2, 15	10, 10, 15	8, 14, 14	
	2, 10, 11	3, 12, 12	8, 11, 11	3, 3, 15	11, 11, 15		
	3, 9, 9	5, 9, 14	8, 12, 12	4, 4, 15	12, 12, 15		
	3, 10, 10	7, 11, 14		5, 5, 15	13, 13, 15		
	4, 9, 13			6, 6, 15	14, 14, 15		
	4, 10, 14			7, 7, 15			
	5, 10, 13			8, 8, 15			
	6, 11, 13						
	6, 12, 14						
7, 12, 13							

Appendix B: Eigenvalues of the general two-level evolution matrix.

The three coupled linear inhomogeneous first-order differential equations (III.1.11-13) or, else, $\dot{\underline{v}} = G\underline{v} + \underline{k}$, with

$$G = \begin{pmatrix} -\gamma_3 & \alpha - \omega_0 & \beta - \omega_2 \\ \alpha + \omega_0 & -\gamma_2 & \delta - \omega_1 \\ \beta + \omega_2 & \delta + \omega_1 & -\gamma_1 \end{pmatrix}, \quad (\text{B.1})$$

are solved by the standard procedure outlined in II. 5. where the construction of eigenvectors is found. The corresponding eigenvalues λ_i are calculated from

$$\lambda^3 + a\lambda^2 + b\lambda + c = 0, \quad (\text{B.2})$$

where

$$a = \gamma_1 + \gamma_2 + \gamma_3, \quad (\text{B.3})$$

$$b = \gamma_1\gamma_2 + \gamma_1\gamma_3 + \gamma_2\gamma_3 + \omega_0^2 + \omega_1^2 + \omega_2^2 - (\alpha^2 + \beta^2 + \delta^2), \quad (\text{B.4})$$

$$c = \gamma_1\gamma_2\gamma_3 + \gamma_1(\omega_0^2 - \alpha^2) + \gamma_2(\omega_2^2 - \beta^2) + \gamma_3(\omega_1^2 - \delta^2) + 2\alpha\omega_1\omega_2 - 2\beta\omega_0\omega_1 + 2\delta\omega_0\omega_2 - 2\alpha\beta\delta. \quad (\text{B.5})$$

The discriminant d of (B.2) is

$$d = \left(\frac{q}{2}\right)^2 + \left(\frac{p}{3}\right)^3, \quad (\text{B.6})$$

in terms of

$$p = b - \frac{a^2}{3}, \quad q = \frac{2}{27}a^3 - \frac{ab}{3} + c. \quad (\text{B.7})$$

With the abbreviations

$$x = \left(-\frac{q}{2} + \sqrt{d}\right)^{1/3}, \quad y = \left(-\frac{q}{2} - \sqrt{d}\right)^{1/3}, \quad (\text{B.8})$$

$$z = \left(\frac{|p|}{3}\right)^{1/2}, \quad \varphi = \frac{1}{3} \arccos(-q/2z^3), \quad (\text{B.9})$$

the roots are as follows:

$$d \geq 0: \quad \begin{cases} \lambda_1 = x + y - \frac{a}{3}, \\ \lambda_2 = -\frac{1}{2}(x+y) + i\frac{\sqrt{3}}{2}(x-y) - \frac{a}{3}, \\ \lambda_3 = -\frac{1}{2}(x+y) - i\frac{\sqrt{3}}{2}(x-y) - \frac{a}{3}, \end{cases} \quad (\text{B.10})$$

$$d < 0: \quad \begin{cases} \lambda_1 = 2z \cos(\varphi) - \frac{a}{3}, \\ \lambda_2 = -2z \cos\left(\varphi - \frac{\pi}{3}\right) - \frac{a}{3}, \\ \lambda_3 = -2z \cos\left(\varphi + \frac{\pi}{3}\right) - \frac{a}{3}. \end{cases} \quad (\text{B.11})$$

Appendix C: Elements of the time-dependent two-level evolution matrix.

We use O_t given in (III.2.3), the abbreviations

$$c = \cos(\omega t) , \quad s = \sin(\omega t) , \quad (C.1)$$

and the frequency detuning

$$\Delta = \omega_0 - \omega \quad (C.2)$$

to obtain \tilde{G}_t of (III.2.6). The list of components is as follows:

$$(\tilde{G}_t)_{11} = -(\gamma_2 s^2 + \gamma_3 c^2) - 2\alpha sc , \quad (C.3)$$

$$(\tilde{G}_t)_{12} = -\Delta - \alpha(s^2 - c^2) + (\gamma_2 - \gamma_3)sc , \quad (C.4)$$

$$(\tilde{G}_t)_{13} = \beta c + (2\omega_1 c - \delta)s , \quad (C.5)$$

$$(\tilde{G}_t)_{21} = \Delta - \alpha(s^2 - c^2) + (\gamma_2 - \gamma_3)sc , \quad (C.6)$$

$$(\tilde{G}_t)_{22} = -(\gamma_2 c^2 + \gamma_3 s^2) + 2\alpha sc , \quad (C.7)$$

$$(\tilde{G}_t)_{23} = \beta s - (2\omega_1 c - \delta)c , \quad (C.8)$$

$$(\tilde{G}_t)_{31} = \beta c - (2\omega_1 c + \delta)s , \quad (C.9)$$

$$(\tilde{G}_t)_{32} = \beta s + (2\omega_1 c + \delta)c , \quad (C.10)$$

$$(\tilde{G}_t)_{33} = -\gamma_1 . \quad (C.11)$$

The constant vector \underline{k} transforms into

$$\tilde{\underline{k}}(t) = -\sqrt{2}(\lambda c + \mu s, \mu c - \lambda s, \nu)^T . \quad (C.12)$$

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