Erratum: Exceptional regions of the 2HDM parameter space [Phys. Rev. D 103, 115012 (2021)]

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Corrections to the published paper require the following modifications.

(1) Following Eq. (6.15), insert the following text and a new equation:

In light of Eq. (6.5) [which was obtained under the assumption that $s_{2\beta} \neq 0$] and Eq. (6.15), it follows that

$$m_{22}^2 - m_{11}^2 = [m_{11}^2 + m_{22}^2 + \lambda v^2]c_{2\beta} = \left[m_A^2 + \frac{1}{2}\lambda v^2(1-R)\right]c_{2\beta}.$$

Hence, if $m_{11}^2 = m_{22}^2$ then either $c_{2\beta} = 0$ or $m_A^2 = \frac{1}{2}\lambda v^2(R-1)$. If the latter is satisfied, then the stability of the vacuum requires that $R > 1$. If in addition $m_{12}^2 \neq 0$ and $c_{2\beta} \neq 0$, then $m_A^2 \neq 0$ in light of Eq. (6.15) which eliminates the possibility of $R = 1$.

(2) The case of $s_{2\beta}c_{2\beta} \neq 0$, $m_{11}^2 = m_{22}^2$ and $m_{12}^2 e^{i\xi} > 0$ was omitted from Table VIII. The corrected version of Table VIII is reproduced below.

(3) Equations (7.5)–(7.7) were exhibited under the unstated assumptions that the corresponding denominators are nonvanishing. A more appropriate form for these three equations (under the assumption that $s_{2\beta'} \neq 0$) is exhibited below, along with two additional clarifying sentences:

$$c_{2\beta'}(m_{11}'^2 + m_{22}'^2 + \lambda' v^2) = m_{22}'^2 - m_{11}'^2, \tag{7.5}$$

$$\frac{1}{2}s_{2\beta'}\cos\xi'(m_{11}'^2 + m_{22}'^2 + \lambda' v^2) = \mathrm{Re}\, m_{12}'^2, \tag{7.6}$$

$$-\frac{1}{2}s_{2\beta'}\sin\xi'[m_{11}'^2 + m_{22}'^2 + (\lambda' - \lambda_5')v^2] = \mathrm{Im}\, m_{12}'^2. \tag{7.7}$$

Equations (7.5) and (7.7) can be used to fix the value of β' and ξ'. However, if $m_{11}'^2 + m_{22}'^2 + \lambda' v^2 = 0$ then it follows that $m_{11}'^2 = m_{22}'^2$ and $\mathrm{Re} m_{12}'^2 = 0$, in which case only $s_{2\beta'}\sin\xi'$ is determined.

(4) Immediately below Eq. (7.21), the following line of text, three new equations (which will result in incrementing by three all subsequent equation numbers in Sec. VII), and three additional lines of text should be inserted:

Hence, we can rewrite Eqs. (7.5) and (7.7) as

$$m_{22}'^2 - m_{11}'^2 = m_A^2 c_{2\beta'}, \tag{7.22}$$

$$\mathrm{Re}\, m_{12}'^2 = \frac{1}{2}s_{2\beta'}\cos\xi' m_A^2, \tag{7.23}$$

$$\mathrm{Im}\, m_{12}'^2 = \frac{1}{2}s_{2\beta'}\sin\xi'(\lambda_5' v^2 - m_A^2). \tag{7.24}$$

For example, suppose that $s_{2\beta'}c_{2\beta'} \neq 0$, $\sin\xi' \neq 0$, $m_{11}'^2 = m_{22}'^2$, and $\lambda_5' \neq 0$. Then, Eqs. (7.22)–(7.24) imply that $m_{12}'^2$ is purely imaginary. Consulting Tables IV and VI, it follows that the scalar potential respects a $\mathrm{U}(1)'$ symmetry

TABLE VIII. Landscape of the ERPS4–Part II(a): Scalar potentials of the 2HDM with either an unbroken or softly broken $U(1) \otimes \Pi_2$ symmetry that is manifestly realized in the Φ basis, where $\lambda \equiv \lambda_1 = \lambda_2$, $\lambda_5 = \lambda_6 = \lambda_7 = 0$, and CP is conserved by the scalar potential and vacuum. The parameter $m_{12}^2 e^{i\xi}$ is real and non-negative [as a consequence of Eqs. (6.4) and (6.14)]; if $m_{12}^2 = 0$ and $s_{2\beta} \neq 0$ then a massless neutral scalar is present in the neutral scalar spectrum. The parameter $R \equiv (\lambda_3 + \lambda_4)/\lambda > -1$; when $R = 1$ the (softly broken) $U(1) \otimes \Pi_2$ symmetry is promoted to a (softly broken) SO(3) symmetry. An exact Higgs alignment in the ERPS4 is realized in the inert limit where $Y_3 = Z_6 = Z_7 = 0$.

β	m_{11}^2, m_{22}^2	$m_{12}^2 e^{i\xi}$	R	Higgs alignment	Comment
$s_{2\beta}c_{2\beta} \neq 0$	$m_{11}^2 \neq m_{22}^2$	>0	$R \neq 1$	No	see Eq. (6.23)
$s_{2\beta}c_{2\beta} \neq 0$	$m_{11}^2 = m_{22}^2$	>0	$R > 1$	No	$m_A^2 = \frac{1}{2}\lambda v^2(R-1)$
$s_{2\beta}c_{2\beta} \neq 0$	$m_{11}^2 \neq m_{22}^2$	0	$\lvert R\rvert < 1$	No	$m_A^2 = 0$
$c_{2\beta} = 0$	$m_{11}^2 = m_{22}^2$	>0	$R \neq 1$	Yes	$-1 < R \leq 1 + 2m_A^2/(\lambda v^2)$
$s_{2\beta} = 0$	$m_{11}^2 \neq m_{22}^2$	0	$R \neq 1$	Yes	$m_H^2 = m_A^2 > 0$
$c_{2\beta} = 0$	$m_{11}^2 = m_{22}^2$	0	$\lvert R\rvert < 1$	Yes	One massless scalar
$s_{2\beta} = 0$	$m_{11}^2 = m_{22}^2$	0	$R > 1$	Yes	$m_H^2 = m_A^2 > 0$
$s_{2\beta}c_{2\beta} \neq 0$	$m_{11}^2 \neq m_{22}^2$	>0	$R = 1$	Yes	$m_H^2 = m_A^2 > 0$
$c_{2\beta} = 0$	$m_{11}^2 = m_{22}^2$	>0	$R = 1$	Yes	$m_H^2 = m_A^2 > 0$
$s_{2\beta} = 0$	$m_{11}^2 \neq m_{22}^2$	0	$R = 1$	Yes	$m_H^2 = m_A^2 > 0$
	$m_{11}^2 = m_{22}^2$	0	$R = 1$	Yes	$m_H^2 = m_A^2 = 0$

that is spontaneously broken. Hence, a massless Goldstone boson exists that can be identified as the CP-odd scalar A.

(5) In light of Eqs. (7.22)–(7.24) above, a number of cases were either not precisely specified or incorrectly omitted from Table IX. The corrected version of Table IX is exhibited below. The equation numbers specified in the caption to the corrected Table IX refer to the three new equations shown above.

TABLE IX. Landscape of the ERPS4–Part II(b): Scalar potentials of the 2HDM with either an unbroken or softly broken GCP3 symmetry that is manifestly realized in the Φ basis. In all cases, $\lambda \equiv \lambda'_1 = \lambda'_2 = \lambda'_3 + \lambda'_4 + \lambda'_5$ (with λ'_5 real and nonzero) and $\lambda'_6 = \lambda'_7 = 0$, and CP is conserved by the scalar potential and vacuum. The results shown in the fourth column for m'^2_{12} have been obtained using Eqs. (7.22)–(7.24). The term "complex" means neither real nor purely imaginary. An exact Higgs alignment in the ERPS4 is realized in the inert limit where $Y_3 = Z_6 = Z_7 = 0$.

β'	ξ'	m'^2_{11}, m'^2_{22}	m'^2_{12}	Higgs alignment	Comment
$s_{2\beta'}c_{2\beta'} \neq 0$	$\sin 2\xi' \neq 0$	$m'^2_{11} \neq m'^2_{22}$	Complex ($\neq$0)	No	
$s_{2\beta'}c_{2\beta'} \neq 0$	$\sin 2\xi' \neq 0$	$m'^2_{11} \neq m'^2_{22}$	Real ($\neq$0)	No	$m_A^2 = \lambda'_5 v^2$
$s_{2\beta'}c_{2\beta'} \neq 0$	$\cos \xi' = 0$	$m'^2_{11} \neq m'^2_{22}$	Purely imaginary ($\neq$0)	No	
$s_{2\beta'}c_{2\beta'} \neq 0$	$\cos \xi' = 0$	$m'^2_{11} \neq m'^2_{22}$	0	No	$m_A^2 = \lambda'_5 v^2$
$s_{2\beta'}c_{2\beta'} \neq 0$	$\sin \xi' \neq 0$	$m'^2_{11} = m'^2_{22}$	Purely imaginary ($\neq$0)	No	$m_A^2 = 0$
$c_{2\beta'} = 0$	$\sin 2\xi' \neq 0$	$m'^2_{11} = m'^2_{22}$	Purely imaginary ($\neq$0)	No	$m_A^2 = 0$
$c_{2\beta'} = 0$	$\sin 2\xi' \neq 0$	$m'^2_{11} = m'^2_{22}$	Real ($\neq$0)	No	$m_A^2 = \lambda'_5 v^2$
$c_{2\beta'} = 0$	$\sin 2\xi' \neq 0$	$m'^2_{11} = m'^2_{22}$	Complex ($\neq$0)	No	$m_A^2 \neq 0,\ \lambda'_5 v^2$
$c_{2\beta'} = 0$	$\sin \xi' = 0$	$m'^2_{11} = m'^2_{22}$	Real ($\neq$0)	Yes	
$c_{2\beta'} = 0$	$\cos \xi' = 0$	$m'^2_{11} = m'^2_{22}$	Purely imaginary ($\neq$0)	Yes	$m_H^2 = m_A^2 \neq 0,\ \lambda'_5 v^2$
$s_{2\beta'}c_{2\beta'} \neq 0$	$\sin \xi' = 0$	$m'^2_{11} \neq m'^2_{22}$	Real ($\neq$0)	Yes	
$s_{2\beta'} = 0$		$m'^2_{11} \neq m'^2_{22}$	0	Yes	
$s_{2\beta'} \neq 0$	$\sin \xi' = 0$	$m'^2_{11} = m'^2_{22}$	0	Yes	One massless scalar
$c_{2\beta'} = 0$	$\cos \xi' = 0$	$m'^2_{11} = m'^2_{22}$	0	Yes	$m_H^2 = m_A^2 = \lambda'_5 v^2$
$s_{2\beta'} = 0$		$m'^2_{11} = m'^2_{22}$	0	Yes	One massless scalar