

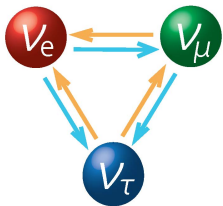
Mapping the viable parameter space for testable leptogenesis

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based on work in collaboration with M. Drewes and J. Klarić
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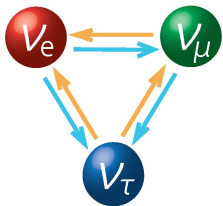
[Planck]

[Chandra]

$\theta_{12} \sim 33^\circ$

$\theta_{13} \sim 9^\circ$

$\theta_{23} \sim 45^\circ$



[Planck]

[Chandra]

] C-zq\$^b \ - ssCs

3 - q%L^CsS

? - qM \ - zzCq

! R^zq@-<S^L ^C...e-qS^Cs <- ^ sbY^C zPCsC ep4Y\ si

>2 pv M2mi`BMQb + M bQHp2 i?`22
T`Q#H2Kb iQM+2,

>2 pv M2mi`BMQb + M bQHp2 i?`22
T`Q#H2Kb iQM+2,

I LQM@x2`Q K bb Q7 i?2 ai M/`/
JQ/2H UaJV M2mi`BMQb pB i?2
ivT2@A bK2b? MBbKX
U_{XJBMFQrbFV}-RNdd

>2 pv M2mi`BMQb + M bQHp2 i?`22
T`Q#H2Kb iQM+2,

I LQM@x2`Q K bb Q7 i?2 ai M/`/
JQ/2H UaJV M2mi`BMQb pB i?2
ivT2@AbK2b? MBbKX
U_XJBMFQrbFV- RNdd

I Pp2`#mM/ M+2 Q7 K ii2`rBi?
`2bT2+iiQ MiBK ii2`i?`Qm;?
H2TiQ;2X2bBb
U_X6mFm;Bi-hXuM;V/- RN3e

>2 pv M2mi`BMQb + M bQH p2 i?`22
T`Q#H2Kb i QM+2,

I LQM@x2`Q K bb Q7 i?2 ai M/`/
JQ/2H UaJV M2mi`BMQb pB i?2
ivT2@AbK2b? MBbKX
UxJBMFQrbFV- RNdd

I Pp2`#mM/ M+2 Q7 K ii2`rBi?
`2bT2+iiQ MiBK ii2`i?`Qm?;
H2TiQ;2X2bBb
Ux6mFm;Bi-hXuM;V/- RN3e

I * M #2. `F J ii2`
+ M/B/ i2
Uq/2HbQMfqB/`Qr- ?2T@T?fnjyjk3d-
b F fa? TQb?MBFQp- ?2T@T?fy8y8yRj

I a22b r G ;` M;B M

$$L \quad 6 \text{ (} \sim \text{) } \text{ - } \frac{R}{k} \text{ + (JJ) } \text{ B D } \text{ + } ? X + X$$

I a22b r G ;` M;B M

$$L \quad 6 \text{ (} \sim \text{) } \text{ -B} \frac{R}{k} \text{ + (JJ) } \text{B D } \text{ } ? X + X$$

. B ` + J D Q ` M

I a22b r G ;` M;B M

$$L \quad 6 \text{ (} \sim \text{) } \text{ - } \frac{R}{k} \text{ + (} J J \text{) } \text{ B D } \text{ + } ? X + X$$

a22b r `2H iBQM

$$K = p^k 6 J J \text{ }^R \text{ } 6i:$$



I a22b r G ;` M;B M

$$L \quad 6 \quad \sim \quad \frac{R}{k} \quad + \quad (J J) \quad B D \quad ? \quad X + X$$

a22b r `2H iBQM

$$K = p^k 6 J J^R 6i:$$



I AMi2` +iBQM bi`2M;i? Q7 i?2 ?2 pv M2mi`BMQ

$$I^k = p^k \underset{;B}{X} j(6 J J^R) \underset{;B}{X} j \underset{;B}{B}^k$$

a F? `Qp +QM/BiBQMb,

a F? `Qp +QM/BiBQMb,
l " `vQM MmK#2` pBQH iBQM

a F? `Qp +QM/BiBQMb,
| " `vQM MmK#2` pBQH iBQM

| * @ M / * S @ pBQH iBQM

a F? `Qp +QM/BiBQMb,
| " `vQM MmK#2` pBQH iBQM

| * @ M/ *S @ pBQH iBQM

| .2pB iBQM 7`QK i?2`K H
2[mBHB#`BmK

a F? `Qp +QM/BiBQMb,
l " `vQM MmK#2` pBQH iBQM
? aT? H2`QM T`Q+2bb

(J@*X *?2M- ?2T@T?fyd)

l * @ M/ *S @ pBQH iBQM

l .2pB iBQM 7`QK i?2`K H
2[mBHB#`BmK

a F? `Qp +QM/BiBQMb,
l " `vQM MmK#2` pBQH iBQM
? aT? H2`QM T`Q+2bb

(J@*X *?2M- ?2T@T?fyd)

l *@ M/ *S@pBQH iBQM
? *S@pBQH iBMX/2+ vb

l .2pB iBQM 7`QK i?2`K H
2[mBHB#`BmK

a F? `Qp +QM/BiBQMb,
| " `vQM MmK#2` pBQH iBQM
? aT? H2`QM T`Q+2bb

(J@*X *?2M- ?2T@T?fyd)

| *@ M/ *S@pBQH iBQM
? *S@pBQH iBMX/2+ vb

| .2pB iBQM 7`QK i?2`K H
2[mBHB#`BmK
? >LGb 7`22x2@Qmi

I . pB/bQM@A# `J_L & # Q: M/B7 K bb ?B2` `+? v
U_R J_k J_j V_X

I . pB/bQM@A# `J_L & # Qj: Mo B7 K bb ?B2` `+? v
U_R J_k J_j V_X
! .2i2+i B_QM

I . pB/bQM@A# `J_L & # Q_N: M_o B7 K bb ?B2` `+? v

U_R J_k J_j V_X

! .2i2+i B_Q_M

G Q_r @ b+ H2 H2 T_i Q; 2 M2 b B_b

I . pB/bQM@A# `J_L & # Qj: Mo B7 K bb ?B2` `+? v

U_R J_k J_j V_X

! .2i2+i BQM

GQr@b+ H2 H2TiQ;2M2bBb

R_V_2bQM H2TiQ;2M2bBb b- ?2T@T?fNdydkj8

I . pB/bQM@A# `J_L & # Qj: Mo B7 K bb ?B2` `+? v

U_R J_k J_j V_X

! .2i2+i BQM

GQr@b+ H2 H2TiQ;2M2bBb

R_V_2bQM H2TiQ;2M2bBb b- ?2T@V?fNdydkj8

! 1M? M+2K2M b Km 2 2 Qp v M2 nKi `bBMQT H BX i B M ; b

I . pB/bQM@A# `J_L & # Qm: M/B7 K bb ?B2` `+? v

U_R J_k J_j V_X

! .2i2+iBQM

GQR@b+ H2 H2TiQ;2M2bBb

R_V_2bQM H2TiQ;2M2bBb - ?2T@T?fnDydkj8

! 1M? M+2K2M bK m2 Qp v M2 nKi`bBMQT H BX i B M ; b

kVG2TiQ;2M2 bB2m7` B M Q Q b + U H i B Q M b

?2T@T?fn3vj k88

I . pB/bQM@A# `J_L & # Q_N: M_o B7 K bb ?B2` `+? v

U_R J_k J_j V X

! .2i2+i B Q M

G Q r @ b + H 2 H 2 T i Q ; 2 M 2 b B b

R V _ 2 b Q M H 2 T i Q ; 2 M 2 b B b b - ? 2 T @ T ? f N d y d k j 8

! 1 M ? M + 2 K 2 M b K m 2 2 Q p v M 2 m k i ` b b M Q T H B X i B M ; b

k V G 2 T i Q ; 2 M 2 b B b m 7 ` B M Q Q b + U H H i B Q M b U H H / Q p f _ m # B Q p f a K B ` M G

? 2 T @ T ? f N 3 y j k 8 8

! S ` Q / m + 2 / / m T B M ; + Q i ? 2 ` K H 2 [m B H B # ` B m K >

I . pB/bQM@A# `J_L & # Qj: Mo B7 K bb ?B2` `+? v

U_R J_k J_j V X

! .2i2+i BQM

GQr@b+ H2 H2TiQ;2M2bBb

R V_2 b Q M H 2 i T i Q ; 2 U 2 b B b b - ? 2 T @ T ? f N d y d k j 8

! 1 M ? M + 2 K 2 M b K m 2 2 Q p v M 2 m k i ` b b M Q T H B X i B M ; b

k V G 2 T i Q ; 2 M 2 b B 2 m 7 ` B M Q Q b + U H H i B Q M b U H K 2 / Q p f _ m # B Q p f a K B ` M G

? 2 T @ T ? f N 3 v j k 8 8

! S ` Q / m + 2 / / m T T B M ; i Q i ? 2 ` K H 2 [m B H B # ` B m K X

! hrQ `2;BK2b Q7 i?2 b K2 K2+? MBbK 5 _2T

b K2 b2i Q7 2[m7i BQM b X + U R V R k X y k e 8 R

$$\frac{B}{\omega} = \left[\frac{g}{k} \right] \frac{B}{k} ; g \frac{B}{k} \sim \frac{1}{h} \omega(R) ;$$

$$\frac{B}{\omega} = \left[\frac{g}{k} \right] \frac{B}{k} ; g + \frac{B}{k} \sim \frac{1}{h} \omega(R) ;$$

$$\frac{1}{\omega} M = \frac{kB}{h} \frac{1}{(k)^j} h[\omega(R)] + B \frac{1}{(k)^j} h[\omega(R)] :$$

$$\frac{B}{\omega} = \left[\frac{1}{k}; \right] \frac{B}{k} ; g \quad B^X \quad \sim \frac{1}{h} \omega (R \omega);$$

$$\frac{B}{\omega} = \left[\frac{1}{k}; \right] \frac{B}{k} ; g + B^X \quad \sim \frac{1}{h} \omega (R \omega);$$

$$\frac{1}{\omega} M = \frac{kB}{h} \frac{Z}{(k)^j} h[\] \omega (R \omega) + B \frac{Z}{(k)^j} h[\sim (\)]:$$

.2MbBiv KfJ`Bd`@ MiBK ii2` bfvKK2i`v
 1z2+iBp2 > KBfAiQIMB +MBQM `i2b

$$\frac{B}{\omega} = \left[\frac{B}{k} \right] \frac{B}{k} ; g \frac{B}{k} \sim \frac{1}{h} \omega(R \omega);$$

$$\frac{B}{\omega} = \left[\frac{B}{k} \right] \frac{B}{k} ; g + \frac{B}{k} \sim \frac{1}{h} \omega(R \omega);$$

$$\frac{1}{\omega} M = \frac{kB}{h} \frac{Z}{(k)^j} h[\] \omega(R \omega) + B \frac{Z}{(k)^j} h[\sim (\)]:$$

.2MbBiv KfJ`B2`@ MiBK ii2` bfvKK2i`v
 1z2+iBp2 > KBfAiQMB +MBQM `i2b

I _ i2b 7`QK EH `B+f a? TQb?MBFQpfhBKB`v b

$$\frac{B}{/i} = [> ;] \frac{B}{k} ; g B^X \sim \frac{1}{h} \zeta(R \zeta);$$

$$\frac{B}{/i} = [> ;] \frac{B}{k} ; g + B^X \sim \frac{1}{h} \zeta(R \zeta);$$

$$\frac{/i}{/i} M = \frac{kB}{h} \frac{Z}{(k)^j} h[] \zeta(R \zeta) + B \frac{Z}{(k)^j} h[\sim ()]:$$

.2MbBiv KfJ`B2`@ MiBK ii2` bfvKK2i`v
 1z2+iBp2 > KBfAiQIMB +MBQM `i2b

| _ i2b 7`QK EH `B+f a? TQb?MBFQpfbKKB`v b
 | J bb ` M;2 7`QK 8y J2o iQ dy h2oX

UEH `B+fa? TQb?MBFQpfbKKB`bv bQ

| R3 M2r T ` K2i2`b BM ivT2@A b22b r,

I R3 M2r T ` K2i2`b BM ivT2@A b22b r,
? j HB;?i M2mi`BMQ K bb2b
? j +QKTH2t M;H2b
? j J DQ` M K bb2b
? j *S@pBQH iBM; T? b2b
? j SJLa M;H2b

| R3 M2r T ` K2i2`b BM ivT2@A b22b r,
 ? j HB;?i M2mi`BMQ K bb2b
 ? j +QKTH2t M;H2b
 ? j J DQ` M K bb2b
 ? j *S@pBQH iBM; T? b2b
 ? j SJLa M;H2b

| *QMbBbi2M@QrB+B HHH iBQM / i BM/m+2/ #v *
 T ` K2i`Bb iBQM

$$6 = \frac{B}{p} \quad q \frac{\text{---}}{K/B} ; p \frac{\text{---}}{J_J}$$

I R3 M2r T ` K2i2`b BM ivT2@A b22b r,
 ? j HB;?i M2mi`BMQ K bb2b
 ? j +QKTH2t M;H2b
 ? j J DQ` M K bb2b
 ? j *S@pBQH iBM; T? b2b
 ? j SJLa M;H2b

I *QMbBbi2M@QrB+B HHH iBQM / i BM/m+2/ #v *
 T ` K2i`Bb iBQM

$$6 = \frac{B}{p} \cdot \frac{q}{K/B} ; \frac{p}{J_j}$$

I J bb /2;2M2` i2 b_j+2M RBMQ`K H Q`/2`BM; M/
 K_{HB};?i2bi y y R 2oX

| R3 M2r T ` K2i2`b BM ivT2@A b22b r,
 ? j HB;?i M2mi`BMQ K bb2b
 ? j +QKTH2t M;H2b
 ? j J DQ` M K bb2b
 ? j *S@pBQH iBM; T? b2b
 ? j SJLa M;H2b

| *QMbBbi2M@QrB+B HHH iBQM / i BM/m+2/ #v *
 T ` K2i`Bb iBQM

$$6 = \frac{B}{p} \cdot \frac{q}{K/B} ; \frac{p}{J_j}$$

| J bb /2;2M2` i2 b_j+2M_jRBMQ`K H Q`/2`BM; M/
 K_{HB};?i2bi y y R 2oX

| h?2Q`2iB+ H +QMbi` BMib,

| R3 M2r T ` K2i2`b BM ivT2@A b22b r,
 ? j HB;?i M2mi`BMQ K bb2b
 ? j +QKTH2t M;H2b
 ? j J DQ` M K bb2b
 ? j *S@pBQH iBM; T? b2b
 ? j SJLa M;H2b

| *QMbBbi2M@QrB+B HHH iBQM / i BM/m+2/ #v *
 T ` K2i`Bb iBQM

$$6 = \frac{B}{p} \cdot \frac{q}{K/B} ; \frac{p}{J_j}$$

| J bb /2;2M2` i2 b_j+2M RBMQ`K H Q`/2`BM; M/
 K_{HB};?i2bi y y 2oX

| h?2Q`2iB+ H +QMbi` BMib,
 S2`im`# iBp2 M_kBi`Biv

| R3 M2r T ` K2i2`b BM ivT2@A b22b r,
 ? j HB;?i M2mi`BMQ K bb2b
 ? j +QKTH2t M;H2b
 ? j J DQ` M K bb2b
 ? j *S@pBQH iBM; T? b2b
 ? j SJLa M;H2b

| *QMbBbi2M@vQrB+B HHH iBQM / i BM/m+2/ #v *
 T ` K2i`Bb iBQM

$$6 = \frac{B}{p} \cdot \frac{q}{K/B} ; \frac{p}{J_j}$$

| J bb /2;2M2` i2 b_j+2M_jRBMQ`K H Q`/2`BM; M/
 K_{HB};?i2bi y y 2oX

| h?2Q`2iB+ H +QMbi` BMib,
 S2`im`# iBp2 M_kBi`Biv
 a22b r 2tT M_kByQM

I R3 M2r T ` K2i2`b BM ivT2@A b22b r,
 ? j HB;?i M2mi`BMQ K bb2b
 ? j +QKTH2t M;H2b
 ? j J DQ` M K bb2b
 ? j *S@pBQH iBM; T? b2b
 ? j SJLa M;H2b

I *QMbBbi2M@vQrB+B HHH iBQM / i BM/m+2/ #v *
 T ` K2i`Bb iBQM

$$6 = \frac{B}{p} \cdot \frac{q}{K/B} ; \frac{p}{J_j}$$

I J bb /2;2M2` i2 b_j+2M_jRBMQ`K H Q`/2`BM; M/
 K_{HB};?i2bi y y 2oX

I h?2Q`2iB+ H +QMbi` BMib,

S2`im`# iBp2 n_kM_kBi`Biv

a22b r 2tT M_kByQM

LQ H `;2` /B iBp2(RQ`_{K₂₂})(_{K_{HQ}})₉ B-Q₉M₉b

I S ` K2i2` bT +2 r v H ` ;2Mi ?k M+2Mi i? QX

| S ` K2i2` bT +2 r v H `;2Mi ?k M+2Mi ?2QX
| _2 +?2b i?2Q`2iB+ H +QMbi` B Mi i HQR K bb2

| 1tT2`BK2Mib rBHH Mmji T2`K Bim i Q T +2X
| * M 2tT2+i iQ T`Q/m+2 i?Qmb M/b Q7 /BbTH +
h2bi #BHBiv 5
| _2bQM Mi H2TiQ;2M2bBb rQ`FBQ(R7 Q2d, bb2b
i2bi #H2X;L ekX

* QM+HmbBQM

| G2TiQ;2M2bBb mM/2` i?2 h2o@b+ H2 Bb pB #
bi`QM;Hv +QmTH2/ ?2 pv M2mi`BMQbX

! aQQM 2tT2`BK2Mi H /2i2+iBQM TQbbB#H2

* QM+HmbBQM

| G2TiQ;2M2bBb mM/2` i?2 h2o@b+ H2 Bb pB #
bi`QM;Hv +QmTH2/ ?2 pv M2mi`BMQbX

! aQQM 2tT2`BK2Mi H /2i2+iBQM TQbbB#H2

| S ` K2i2` bT +2 Km+? H `; ~~DE~~ ik?bM27M` B?QX LQ
#QmM/ 7`QK H2TiQ;2M2bBb BM i?2 HQR K bb `

; b^<Y-sb^

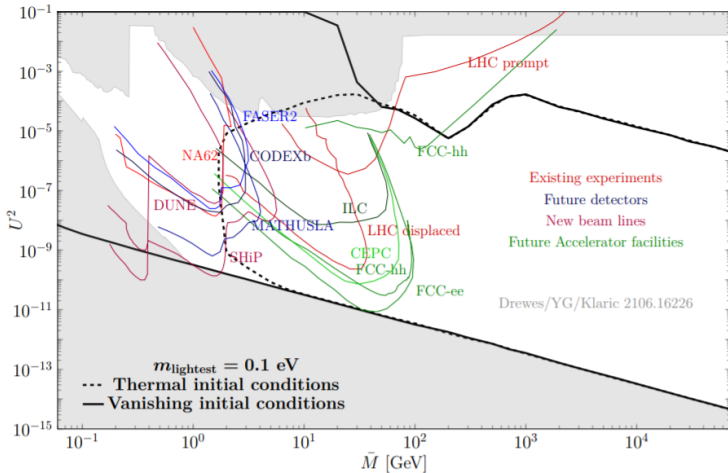
| XGezblC^CsS ~^@CqzPC yC G<-YC S - fS 4C sbY-zb^>CfC^ Hbq
szp^LY%ab-eV@PG-f%G-zp^bsi

! r bb^ CteCq\ C^z-Y@CzC-zb^ ebssS4YCF

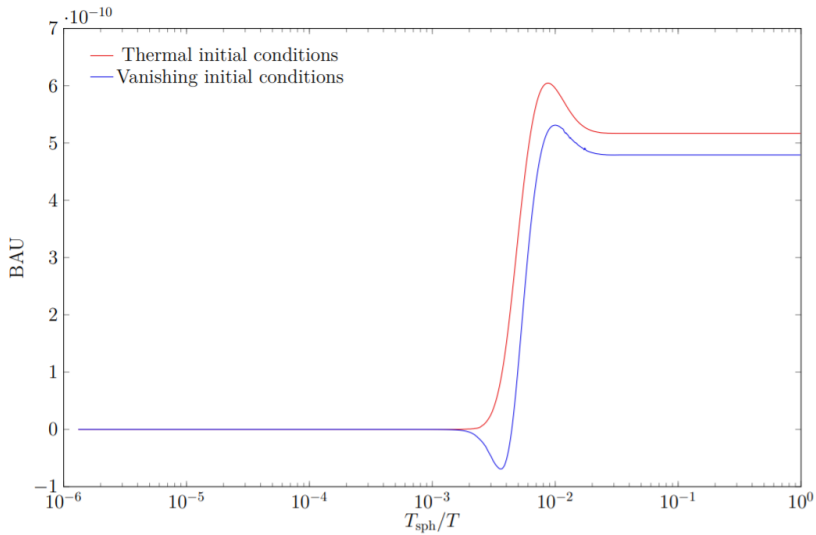
| d-q\ CzCqse-<C\ ~P Yq.CqzP-^ HbqzPC ^ = | s<C^-qbi] b ~eeCq
4b~^@Hp\ YgezblC^CsS S^ zPC Yb... \ -ss q^LQ

| XGezblC^CsS ..zP zPCq\ -YS^SS Y<b^@zb^s S ebssS4YCF Hbq\ -ssCs -s
Yb...-s.c.u KC i

3 - We sys@Cs



$$|d - q \setminus CzCq se - \langle C s \setminus - YCq Hbq \setminus y_{LPzCsZ} = CEC C i$$



$$] - \mathcal{F}C \text{ sOCs} - \dots 4b \sim \wedge @$$

$$\} \frac{2}{S} \frac{q \frac{\sqrt{-z^2} + \sqrt{Pz}}{l}}{l} \cdot c \mathbb{E}^{10} \frac{KC}{l s}$$

$$] - \mathcal{F}C \text{ sOCs-... } 4b \sim \wedge @$$

$$q \frac{\sqrt{-z^2} + \sqrt{z^2}}{l} \cdot c \mathcal{E}^{10} \frac{KC}{l s}$$

30X - eed†S - zC s%o \ Czq%o

$$[- Ubq \wedge - \backslash - ss$$

	\circ	c	\mathcal{E}	\mathcal{E}^1
l	$@$	\mathcal{E}	$c +$	\mathcal{E}^A
		\mathcal{E}	\mathcal{E}	0

$$\wedge \sim W \dots \langle b \sim e \mathcal{S} \mathcal{L}$$

\circ	$H(c + d)$	$\mathcal{H}(c + d)$	H^0	\mathcal{H}^0	1
$@$	$H(c +)$	$\mathcal{H}(c +)$	H^0	\mathcal{H}^0	A
	$H(c +)$	$\mathcal{H}(c +)$	H^0	\mathcal{H}^0	

Hbq ; ; ⁰ c: