Some neutrino highlights and Ernest Ma

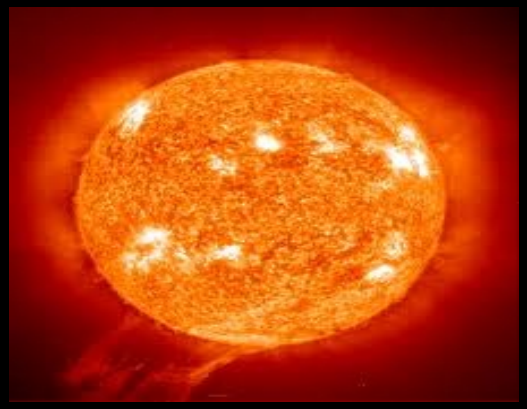
José W F Valle

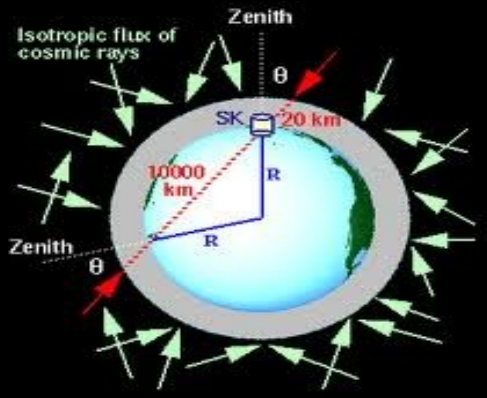
IFIC AHEP on facebook

Manzanillo, July 2015, Mexico

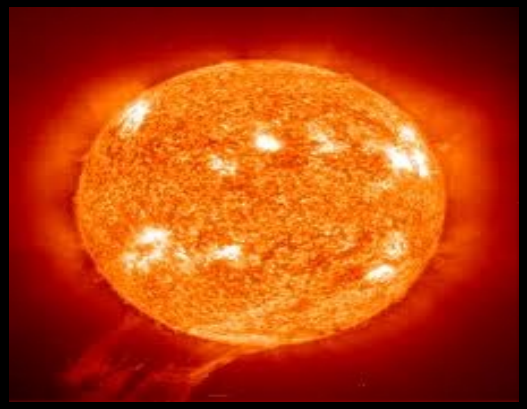
Big Bang

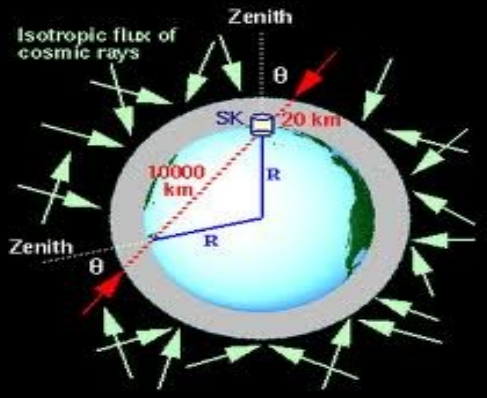
Big Bang

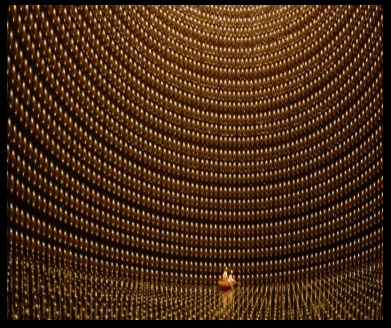



Isotropic flux of cosmic rays
Zenith
θ
SK
20 km
10000 km
R
R
Zenith
θ

Big Bang

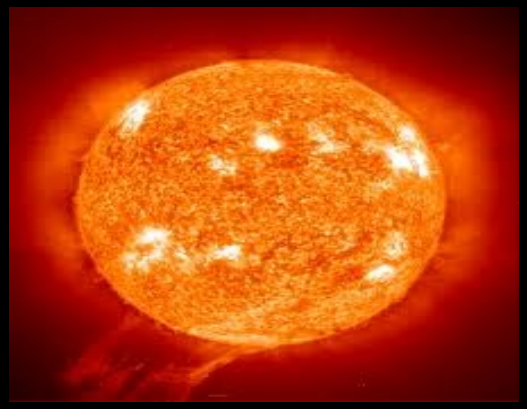


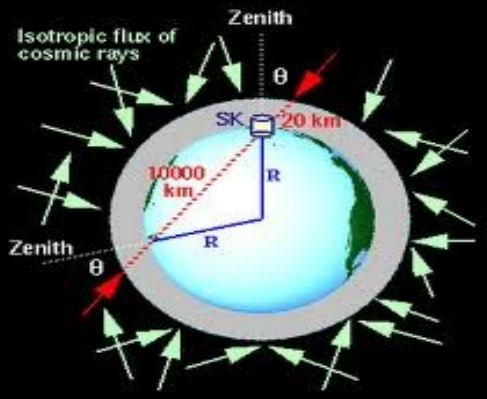




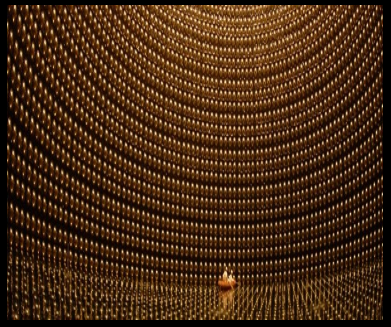
JWF Valle

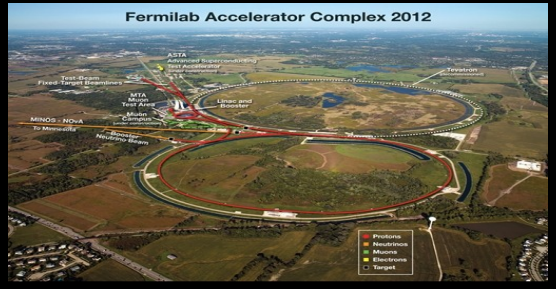
Big Bang



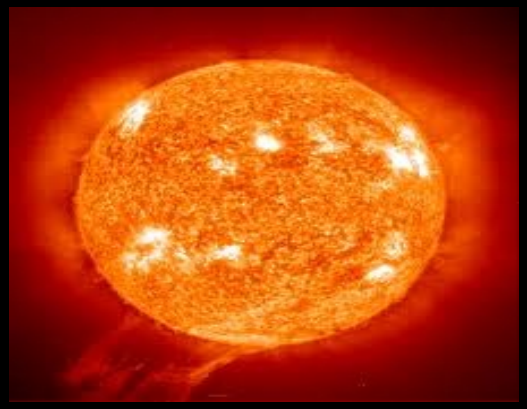


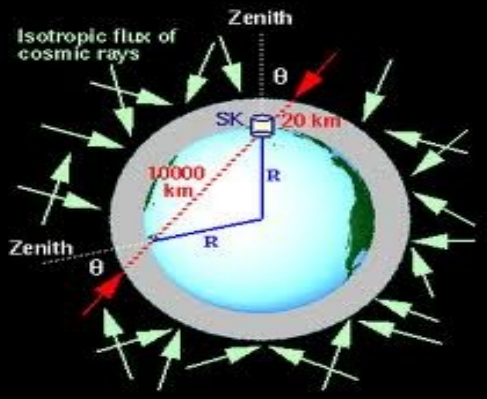
Confirmed

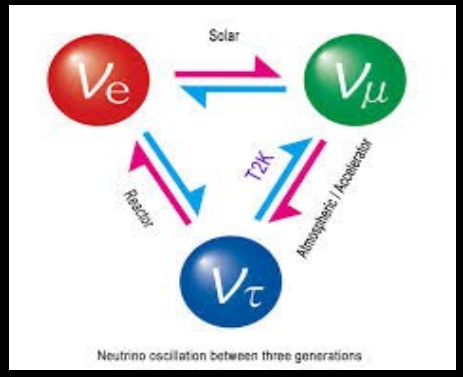




Big Bang







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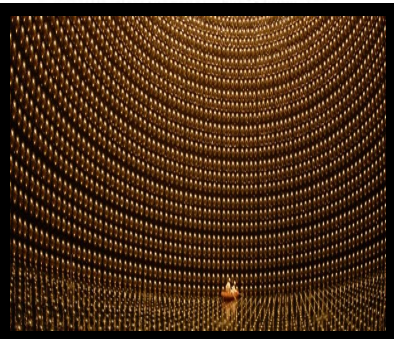
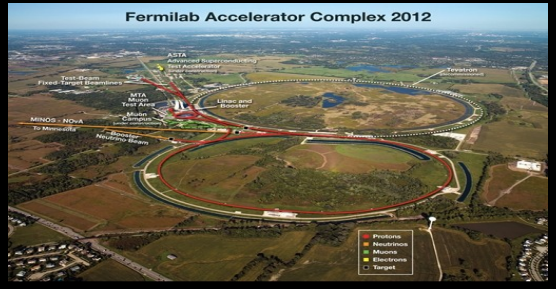
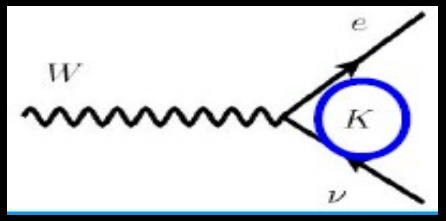




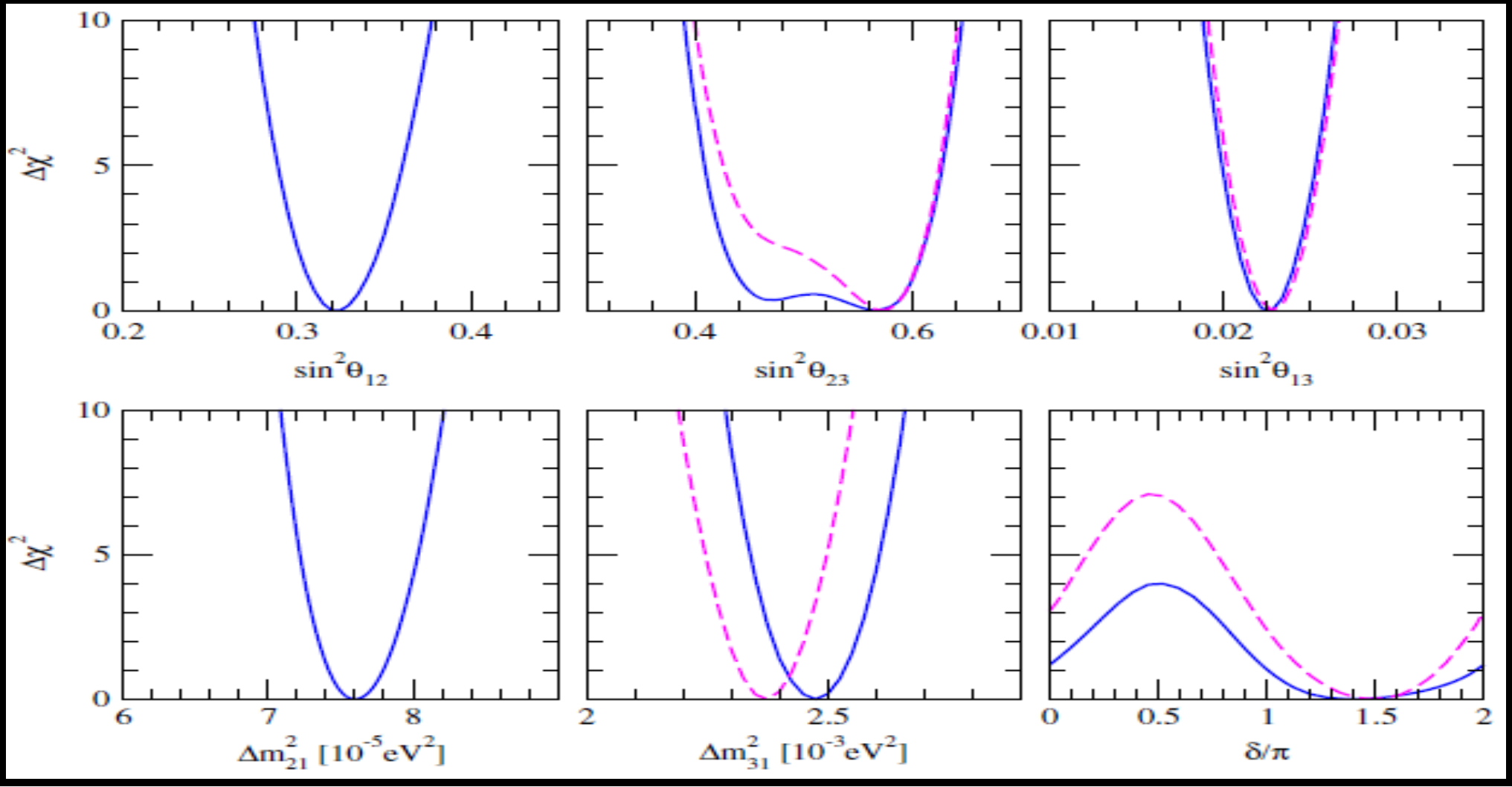
NEUTRINO MIXING & OSCILLATIONS

Schechter & JV PRD22 (1980) 2227 & PDG

Rodejohann, JV Phys.Rev. D84 (2011) 073011



PHYSICAL REVIEW D **90,** 093006 (2014)



Great achievement but

Q1- *Why mass scale so different from charged fermions?*

Q2- *Why mixing so different from CKM?*

Great achievement but

Q1- *Why mass scale so different from charged fermions?*

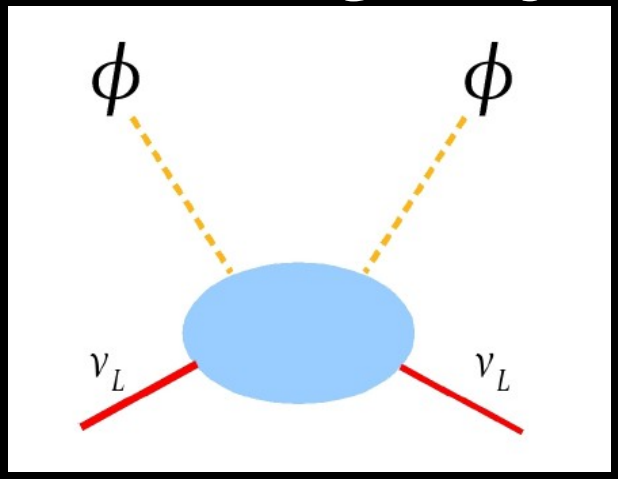
Because of LNV, e.g. seesaw

Q2- *Why mixing so different from CKM?*

Because of some flavor symmetry, e.g. A4

neutrinos as gateways to new physics

origin of neutrino mass and seesaw



fermion exchange
TYPE I
Minkowski 77
Gellman Ramond Slansky 80
Glashow, Yanagida 79
Mohapatra Senjanovic 80
Lazarides Shafi Weterrich 81
Schechter-Valle, 80 & 82

Scalar-exchange
TYPE II
Schechter-Valle 80/82

SCALE

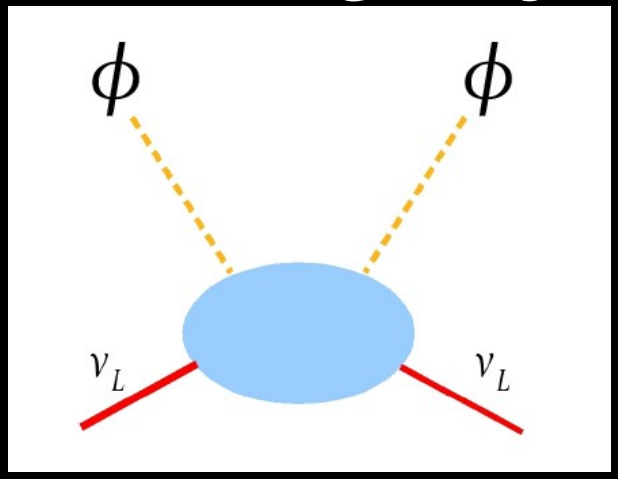
$$v_3 v_1 \sim {v_2}^2 \quad \text{with} \quad v_1 \gg v_2 \gg v_3$$

MECHANISM Number & properties of messengers

FLAVOR STRUCTURE

LOW-SCALE SEESAW
Mohapatra-Valle 86
Akhmedov et al PRD53 (1996) 2752
Malinsky et al PRL95(2005)161801
Bazzocchi et al, PRD81 (2010) 051701

origin of neutrino mass and seesaw



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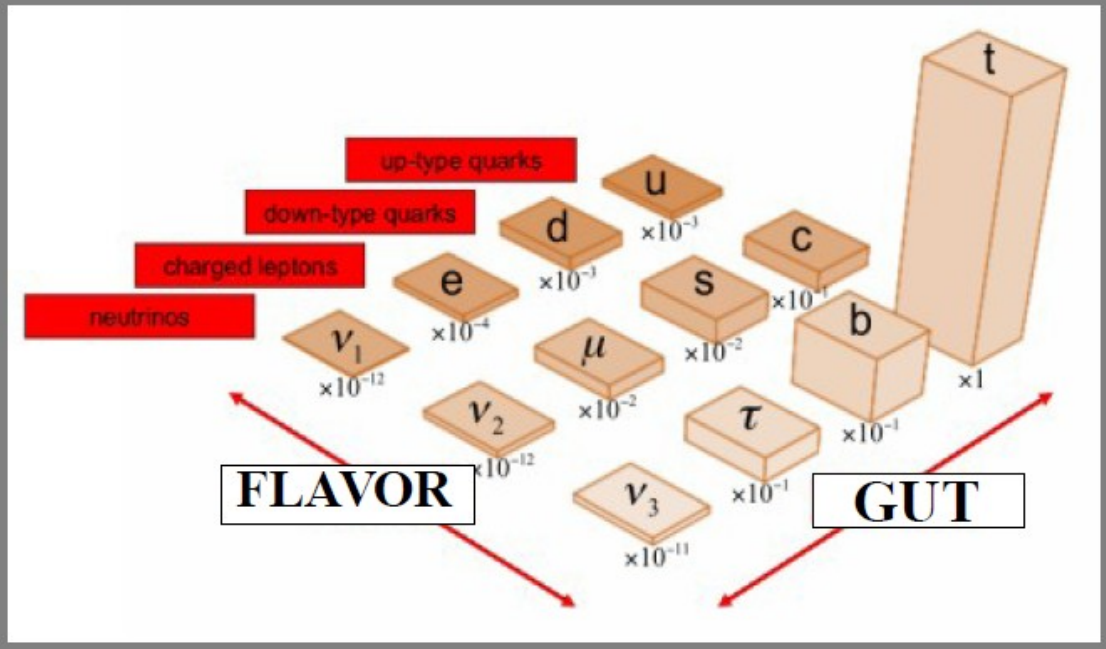
Pathways to Naturally Small Neutrino Masses

Ernest Ma
partment of Physics, University of California, Riverside, California 92521
(Received 11 May 1998)

Flavor problem



pattern of oscillation parameters …

pattern of charged fermion masses…

$$\frac{m_\tau}{\sqrt{m_e m_\mu}} \approx \frac{m_b}{\sqrt{m_d m_s}},$$

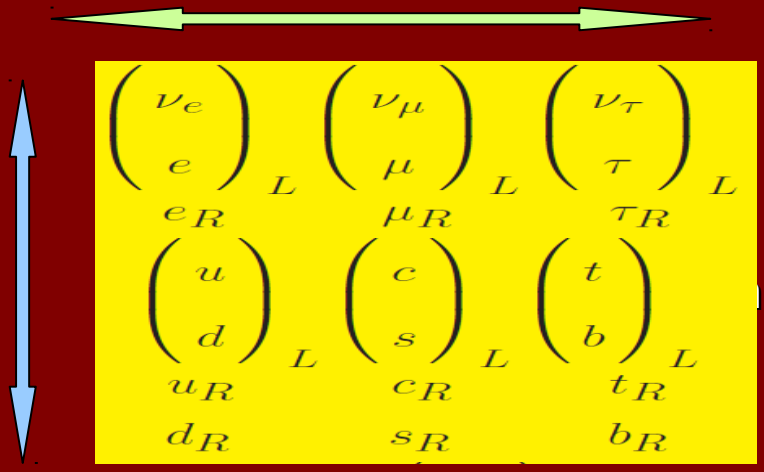
b-tau unification without GUTS…

Morisi et al Phys.Rev. D84 (2011) 036003

King et al Phys. Lett. B 724 (2013) 68

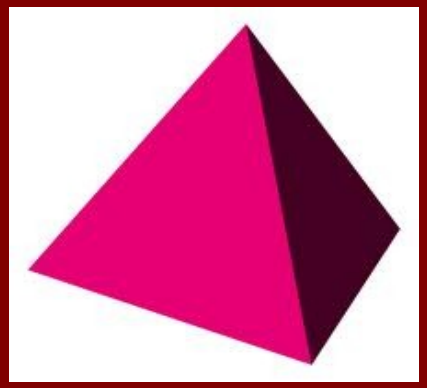
Morisi et al Phys.Rev. D88 (2013) 036001

Bonilla et al Phys.Lett. B742 (2015) 99



FLAVOR SYMMETRY

A4



$\sin^2\theta_{23} = 0.5$

$\sin^2\theta_{13} = 0$

arXiv:1305.6774

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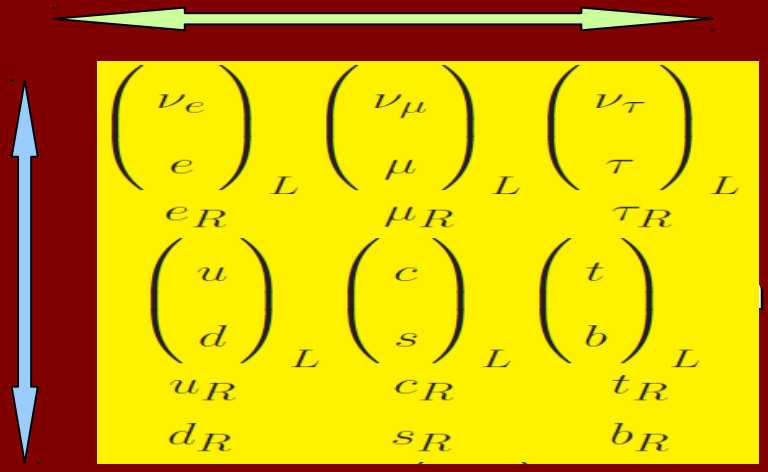
Nilles, Morisi, JV



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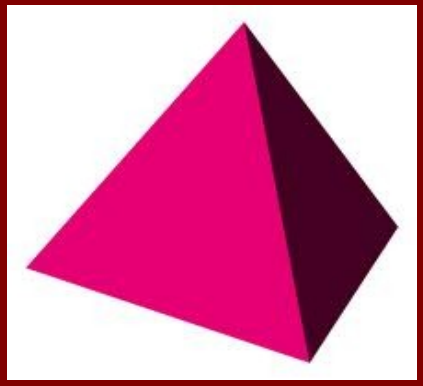

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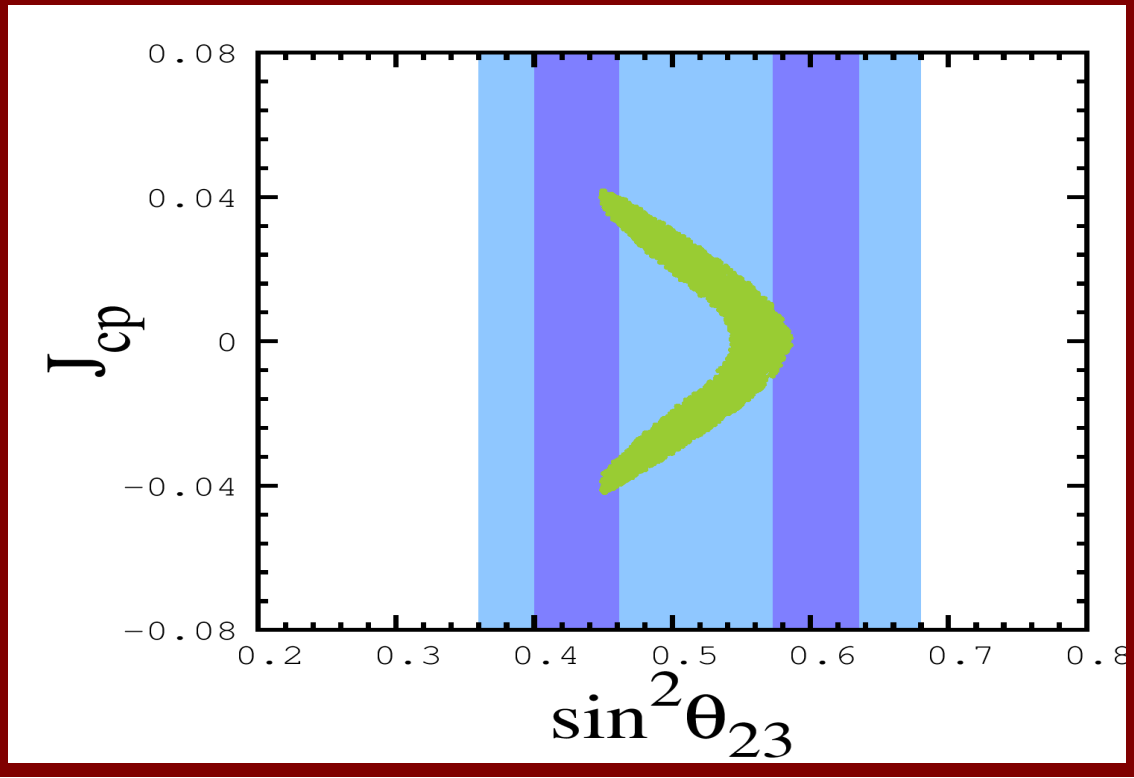
PREDICTION

arXiv:1305.6774



PHYSICAL REVIEW D, VOLUME 64, 113012

Softly broken A_4 symmetry for nearly degenerate neutrino masses

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ELSEVIER

Physics Letters B 552 (2003) 207–213

Underlying A_4 symmetry for the neutrino mass matrix and the quark mixing matrix

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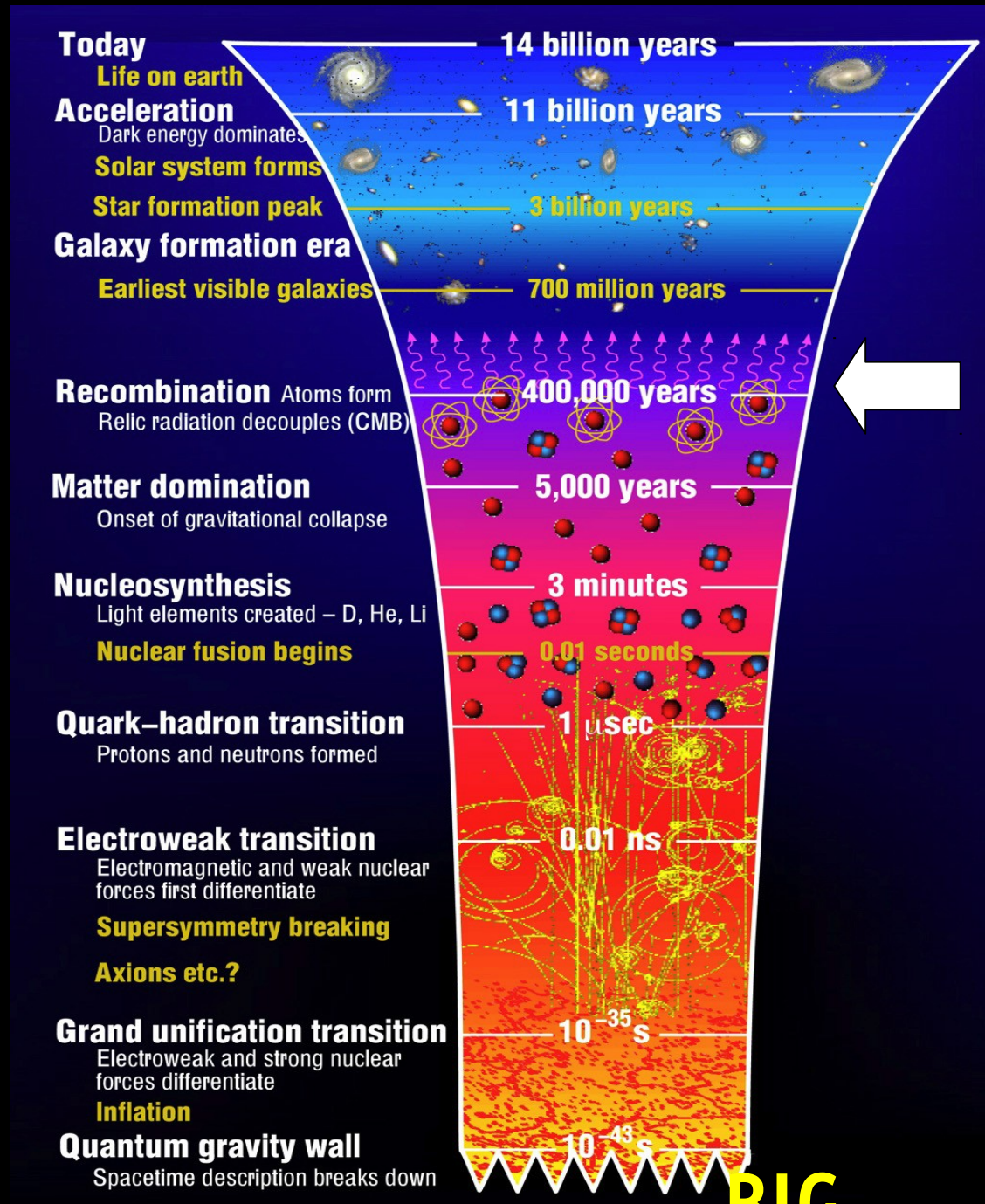
[a] *Physics Department, Oklahoma State University, Stillwater, OK 74078, USA*
[b] *Physics Department, University of California, Riverside, CA 92521, USA*
[c] *Instituto de Física Corpuscular, CSIC, Universitat de València, Edificio Institutos, Aptdo. 22085, E-46071 València, Spain*

Received 29 October 2002; received in revised form 25 November 2002; accepted 2 December 2002

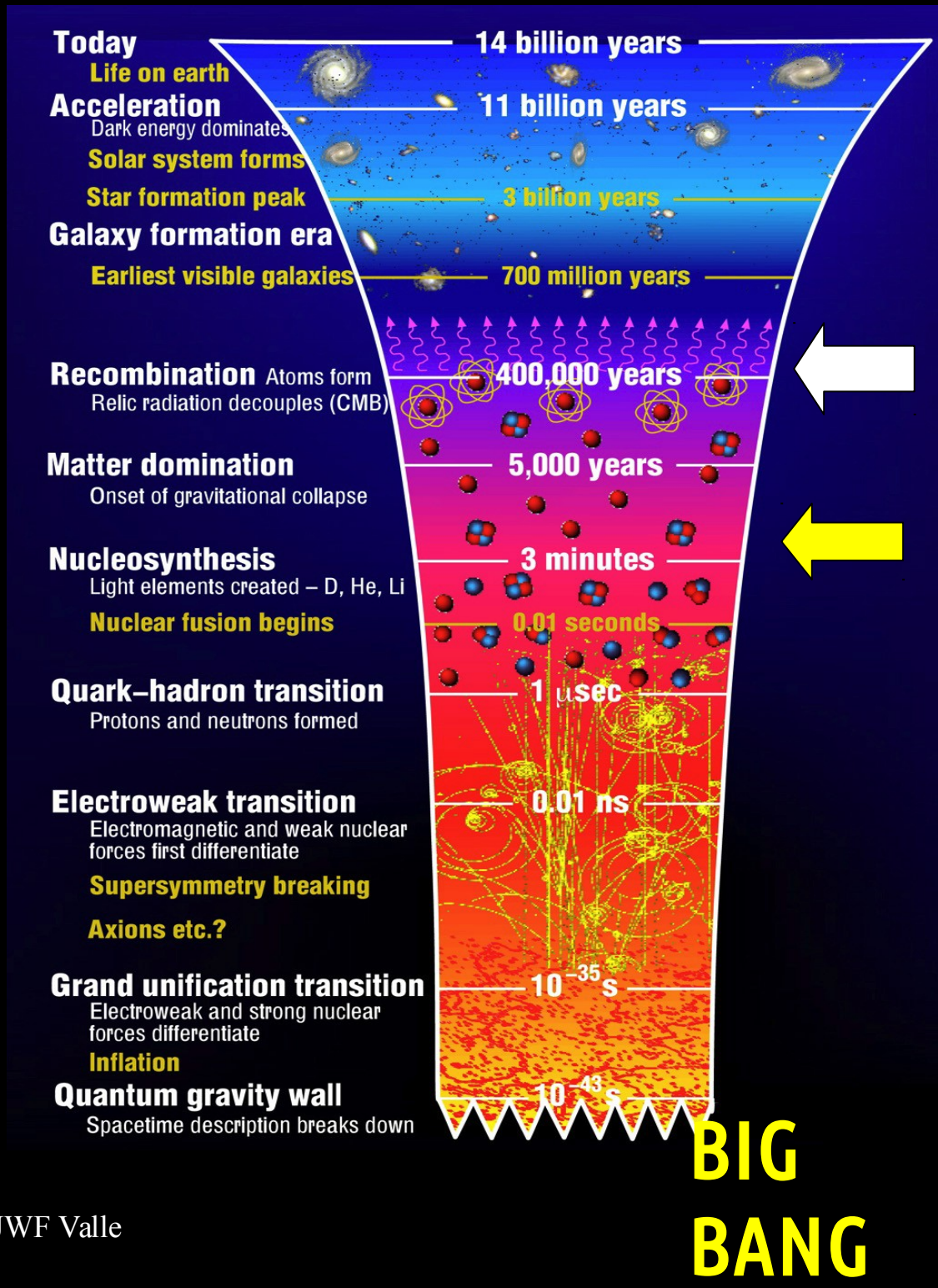
Editor: G.F. Giudice

Neutrinos affect the CMB and large scale structure in the Universe …



Neutrinos affect the CMB and large scale structure in the Universe …

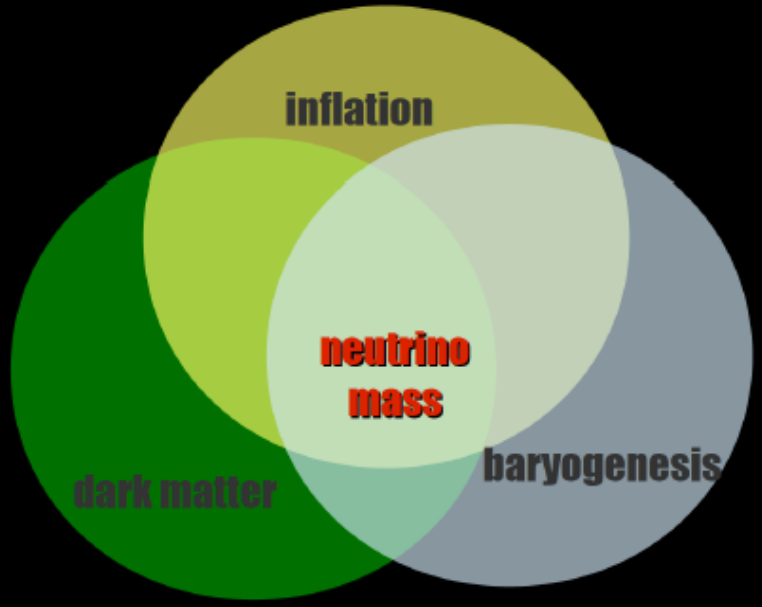
are key in the synthesis of light elements

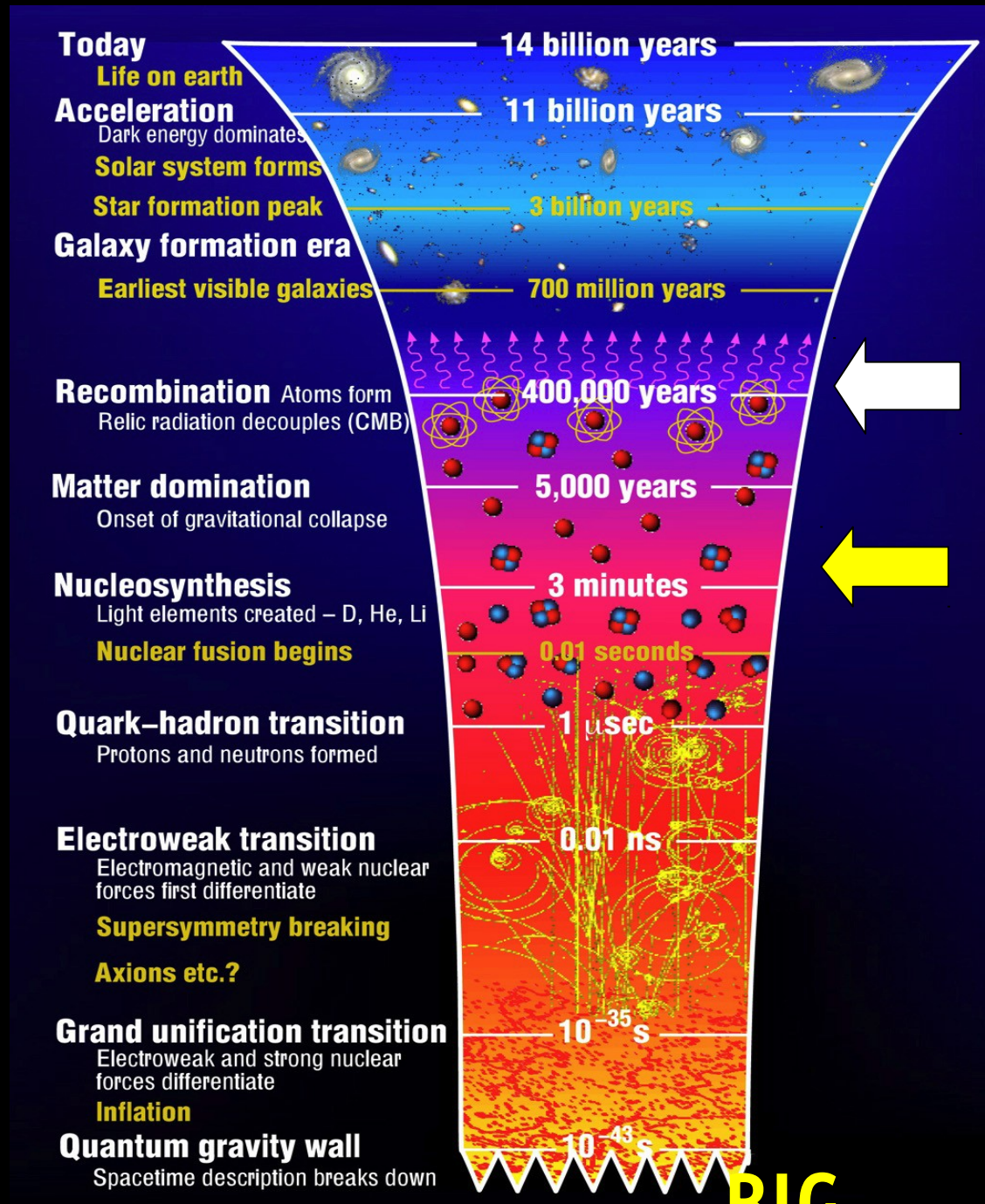


Neutrinos affect the CMB and large scale structure in the Universe …

are key in the synthesis of light elements

can "probe" the Universe earlier than photons …





Verifiable radiative seesaw mechanism of neutrino mass and dark matter

Ernest Ma

Physics Department, University of California, Riverside, California 92521, USA

(Received 27 January 2006; published 14 April 2006)

Neutrino oscillations have established that neutrinos ν_i have very small masses. Theoretically, they are believed to arise through the famous seesaw mechanism from their very heavy and unobservable Dirac mass partners N_i. It is proposed here in a new minimal extension of the standard model with a second scalar doublet (η^+, η^0) that the seesaw mechanism is actually radiative, and that N_i and (η^+, η^0) are experimentally observable at the forthcoming Large Hadron Collider, with the bonus that the lightest of them is also an excellent candidate for the dark matter of the Universe.

How Many Neutrinos?

Ernest Ma and Jon Okada

Department of Physics and Astronomy, University of Hawaii at Manoa, Honolulu, Hawaii 96822

(Received 24 March 1978)

Measurement of $e^+e^- \to \gamma\nu\bar{\nu}$ at the new colliding-beam facilities can determine directly the total number of neutrino types (ν_e, ν_μ, ν_τ, etc.).

Thank you ...

Thank you Ernest !!