Abingdon, Coseners House, 8 June, 2009

Flavour physics in the era of precision neutrino experiments:

neutrinos in astrophysics

and

cosmology

- What measurements on neutrino properties can we expect from cosmology/astrophysics?
- How do they compare to terrestrial information?

Cosmology can test the expectation from SM to the contribution of the expansion rate of the Universe

USING WMAP3+SDSS-LRG+SNI-A

$$N_\nu = 3.9^{+2.0}_{-1.6}\ (95\%\ \text{C.L.})$$

HAMANN, STH, RAFFELT, WONG arXiv:0705.0979 (JCAP)

$N_\nu = 0$ IS EXCLUDED AT ABOUT 5 SIGMA!

...and it also provides important information on the absolute neutrino mass scale

Neutrino masses: $m_1 < m_2 < m_3$

neutrino mixing data

2 possible schemes: normal or inverted

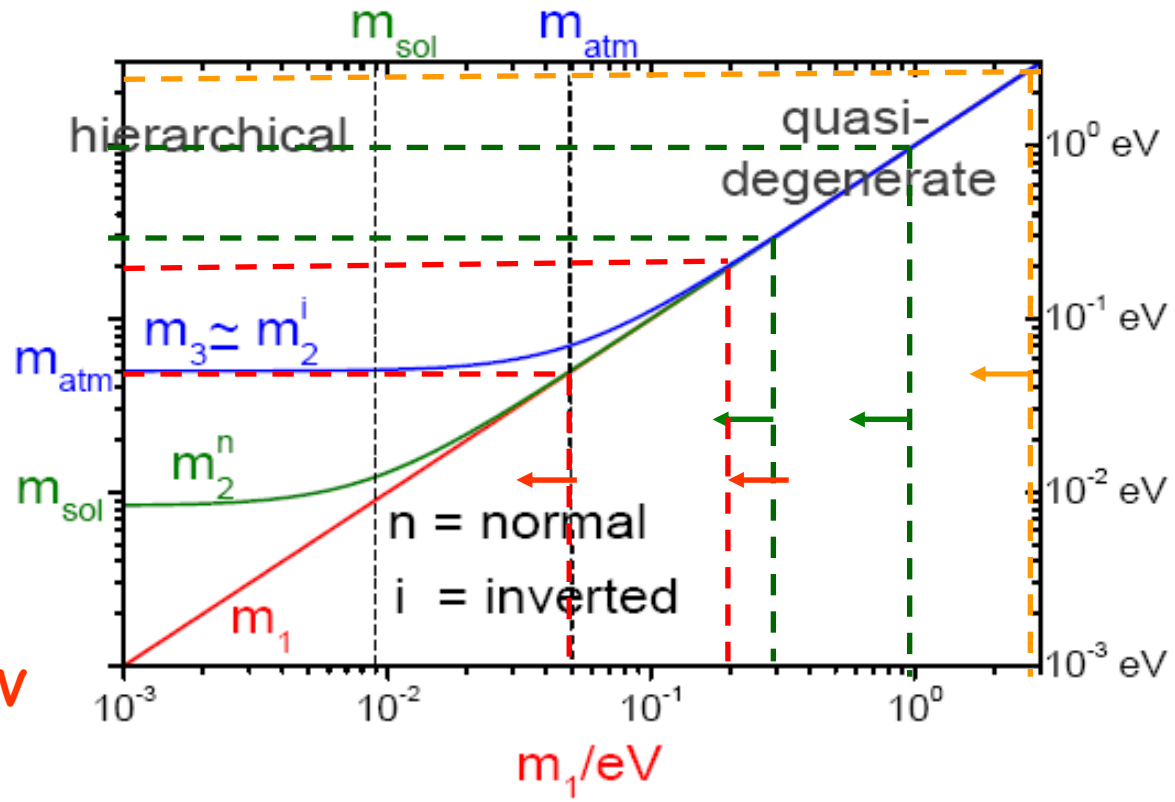
$$m_3^2 - m_2^2 = \Delta m^2_{\rm atm} \text{ or } \Delta m^2_{\rm sol} \qquad m_{\rm atm} \equiv \sqrt{\Delta m^2_{\rm atm} + \Delta m^2_{\rm sol}} \simeq 0.05\,{\rm eV}$$

$$m_2^2 - m_1^2 = \Delta m^2_{\rm sol} \text{ or } \Delta m^2_{\rm atm} \qquad m_{\rm sol} \equiv \sqrt{\Delta m^2_{\rm sol}} \simeq 0.009\,{\rm eV}$$

Tritium β decay :m_e<2.3 eV
(Mainz 95% CL)

$\beta\beta0\nu$:$m_{\beta\beta}$< 0.3 – 1.0 eV
(Heidelberg-Moscow 90% CL, similar result by CUORICINO)

using the flat prior (Ω_0=1):
CMB+BAO : Σ m_i < 0.61 eV
(WMAP5+SDSS)
CMB+LSS + Lyα :Σ m_i <0.17 eV
(Seljak et al.)



A comparison of results from cosmology and neutrinoless double-beta decay could constraint the Majorana neutrino mass term if cosmology points to a value for the sum of neutrino masses compatible with inverted hierarchy no evidence for ββ0ν is found

$\Longrightarrow$ this would disprove leptogenesis (see Nardi's summary)

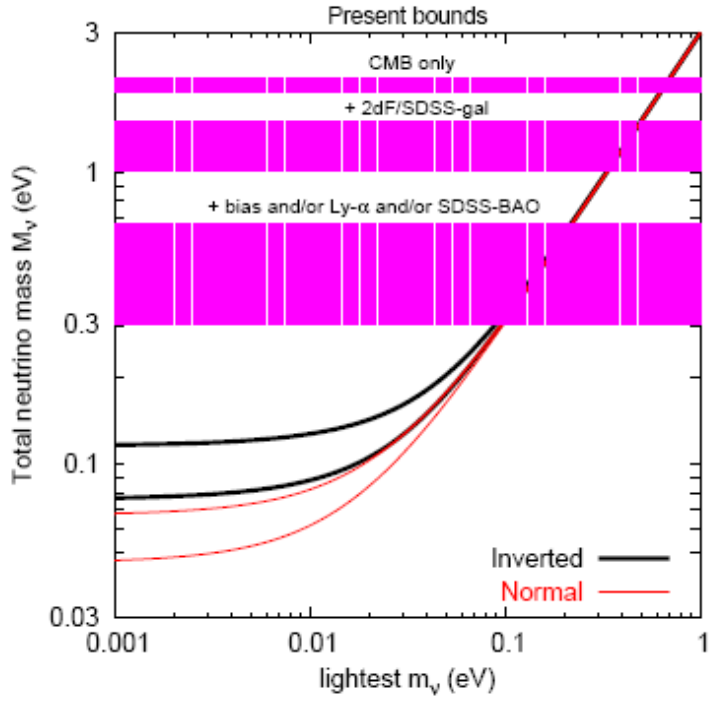


Fig. 19. Current upper bounds (95%CL) from cosmological data on the sum of neutrino masses, compared to the values in agreement at a 3σ level with neutrino oscillation data in Eq. (2).

Julien Lesgourgues [a] and Sergio Pastor [b]

Collective flavor transitions of supernova neutrinos

Neutrino mixing cannot be tested with cosmology, while Detection of neutrinos from SN could potentially test small values of θ_{13} though at the moment theoretical uncertainties in tracking the evolution of the flavor compositions are still too large

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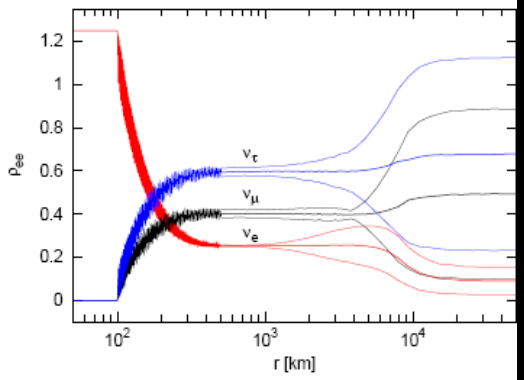
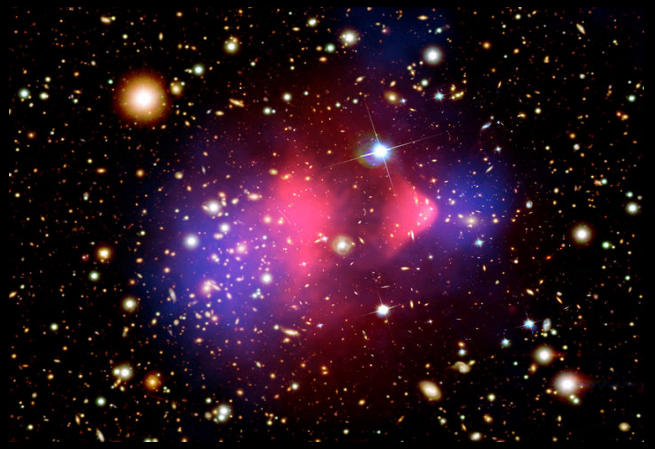


Figure 1. Radial evolution of the fluxes of ν_e (red), ν_μ (black) and ν_τ (blue) fluxes, normalized to the initial $\bar{\nu}_e$-flux, for a fixed neutrino energy $E = 20\,\mathrm{MeV}$ and an inverted atmospheric hierarchy. For the neutrino parameters we use $\Delta m^2_{12} = \Delta m^2_{\rm sol} = 7.65 \times 10^{-5}\ \mathrm{eV}^2$, $\Delta m^2_{13} = \Delta m^2_{\rm atm} = 2.4 \times 10^{-3}\ \mathrm{eV}^2$, $\sin^2\theta_{12} = 0.304$, $\sin^2\theta_{13} = 0.01$, $\sin^2\theta_{23} = 0.4$, and a vanishing Dirac phase $\delta = 0$, all consistent with measurements [20]. The mat-

Cosmology provides today many convincing evidences (e.g. the 'bullet cluster') about the presence of a dark matter component that seems to require an explanation in terms of a new weakly coupled particle sufficiently heavy to be "cold"



Recent results on electron-positron fluxes in cosmic rays from the PAMELA and FERMI experiments have been interpreted by many groups in terms of annihilating or decaying DM but FIRST an astrophysical solution e.g. in terms of pulsars can well explain the results, SECOND the same data are not fully convincing (as pointed out by De Rujula in the discussion). Future FERMI results on diffuse photon background could shed light on this point. An alternative DM solution in terms of neutrino phyisics (unrelated to PAMELA-FERMI data) has been discusses by A. Kusenko (see talk).