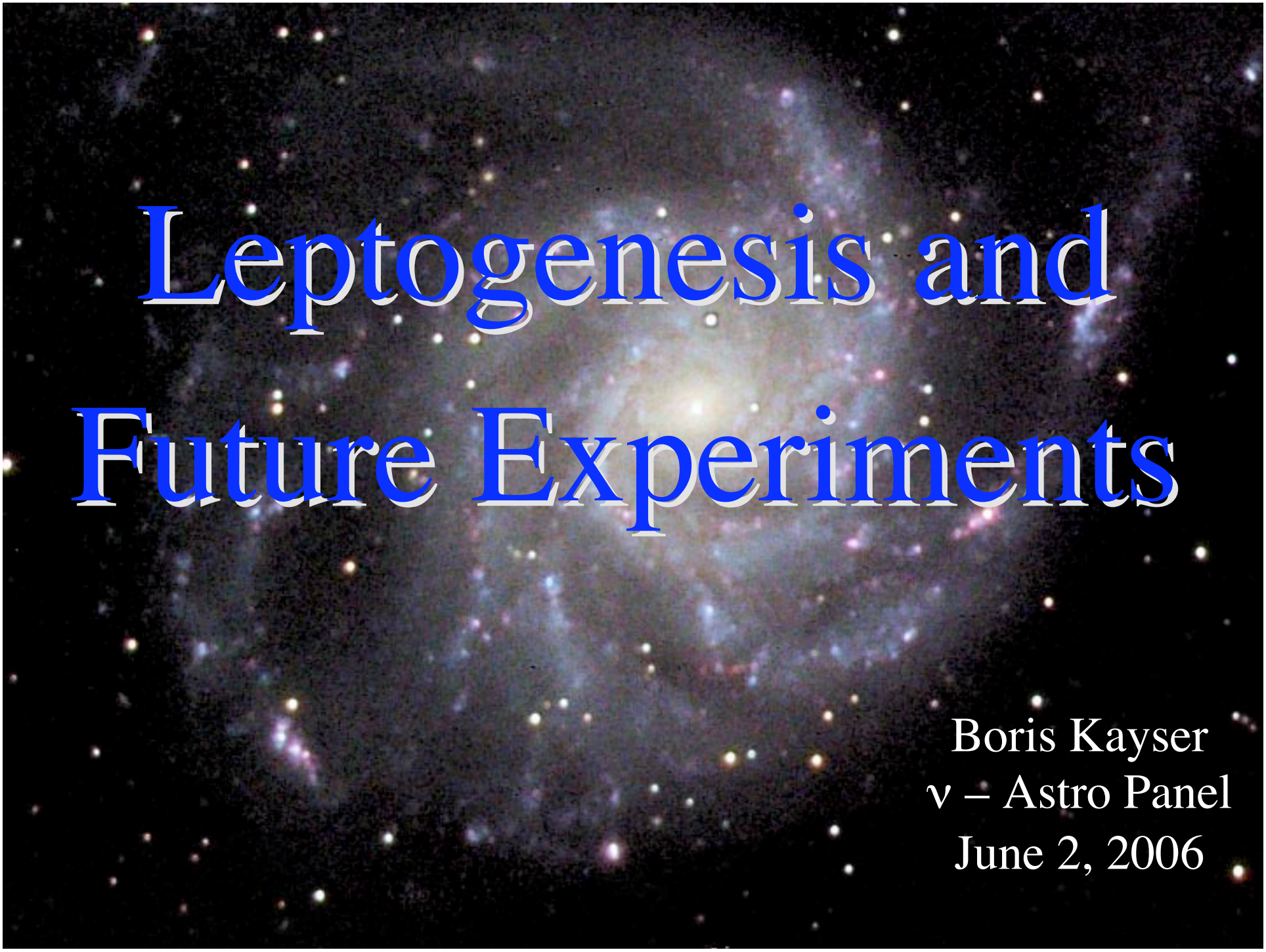
Leptogenesis and
Future Experiments
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ν – Astro Panel
June 2, 2006

The Puzzle

Why does the universe contain **MATTER**,
but almost no antimatter?

Cosmology: In the earliest moments, there were equal amounts of the two.

The **MATTER** – antimatter asymmetry developed later.

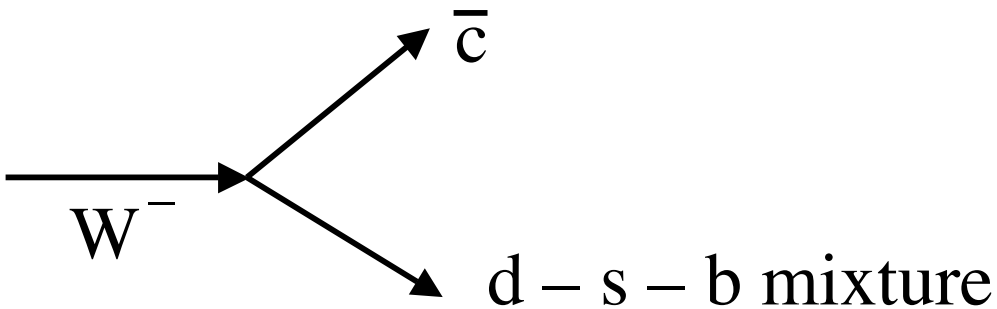
This development required CP violation
(a difference between the behavior of **MATTER** and that of antimatter).

The CP Violation ($\not{CP}$) That Doesn't Work

The behavior of **QUARKS** differs from that of **ANTIQUARKS**.

The observed difference is beautifully described as coming from Standard-Model quark mixing.

Example of mixing:

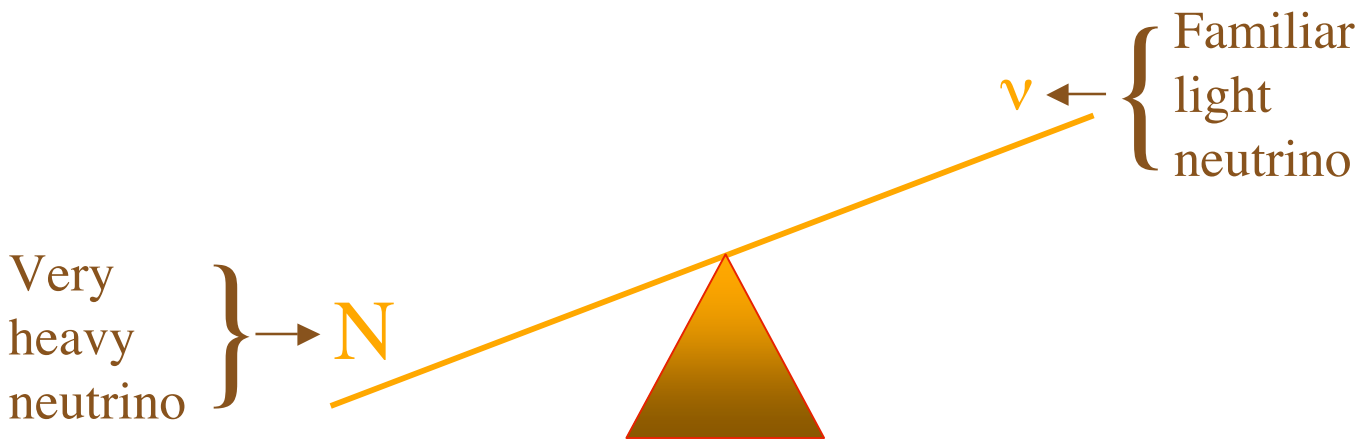


In the **hot** early universe, where quark masses are negligible, quark mixing becomes meaningless. ***No $\not{CP}$.***

The $\not{CP}$ That Might Well Work

The most popular theory of why neutrinos are so light is the —

See-Saw Mechanism



The heavy neutrinos N would have been made in the hot Big Bang.

The heavy neutrinos N, like the light ones ν, are Majorana particles. Thus, an N can decay into ℓ^- or ℓ^+.

If neutrino oscillation violates CP, then quite likely so does N decay.

Then, in the early universe, we would have had different rates for the CP-mirror-image decays –

$$N \rightarrow \ell^- + \ldots \qquad \text{and} \qquad N \rightarrow \ell^+ + \ldots$$

This would have led to unequal numbers of leptons and antileptons **(Leptogenesis)**.

Perhaps this was the original source of the present preponderance of Matter over Antimatter in the universe.

Leptogenesis and the Masses of the Light Neutrino Mass Eigenstates ν_i

The hypothesis that the matter-antimatter asymmetry of the universe is due to Leptogenesis suggests that —

$$\text{Mass[Each } \nu_i] < 0.13 \text{ eV}.$$

(Buchmüller, Di Bari, Plümacher)

{Assumes hierarchical (non-degenerate) N_i}

From oscillation and cosmological data —

$$0.04 \text{ eV} \lesssim \text{Mass[Heaviest } \nu_i] < (0.1 - 0.4) \text{ eV}.$$

Coincidence??

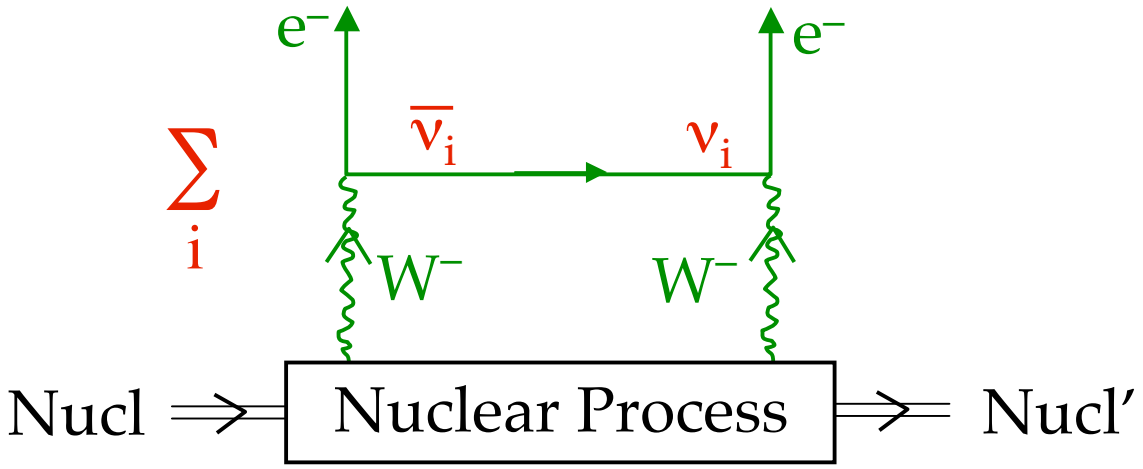
How to Lend Credence to the Hypothesis of Leptogenesis

1. Confirm that the light neutrinos mass eigenstates ν_i are Majorana particles ($\overline{\nu}_i = \nu_i$).

Equivalently, show that the Lepton Number L defined by—
$L(\nu) = L(\ell^-) = -L(\nu) = -L(\ell^+) = 1$ is not conserved.

Then nothing distinguishes $\overline{\nu}_i$ from ν_i .

To Demonstrate That $\overline{\nu}_i = \nu_i$: Neutrinoless Double Beta Decay $[0\nu\beta\beta]$



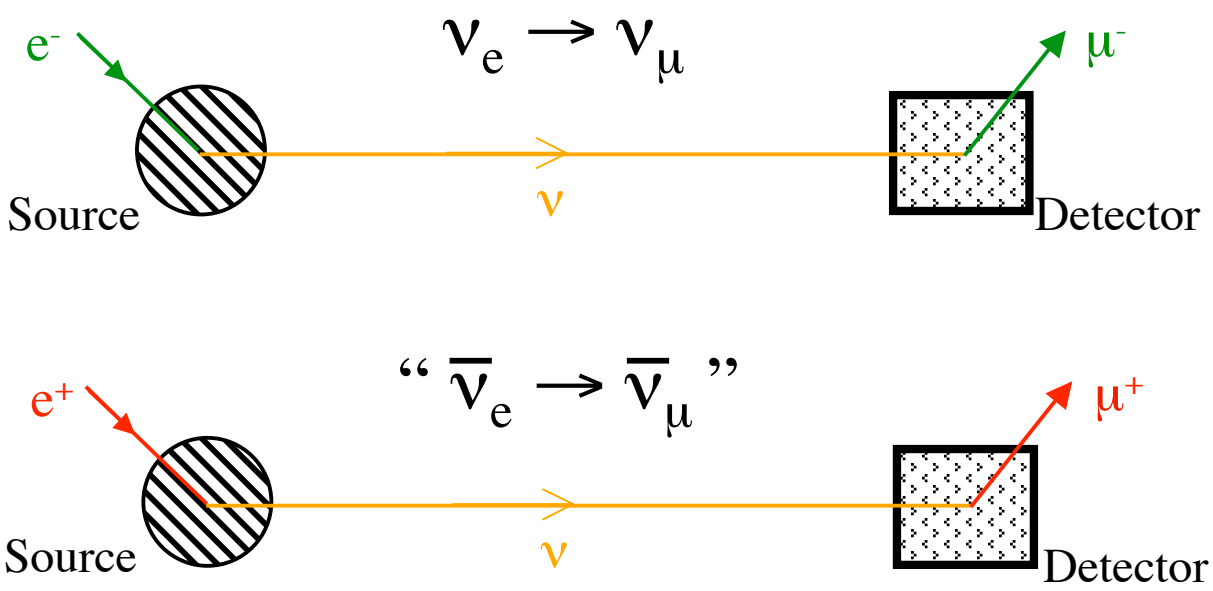
Observation would imply $\not{L}$ and $\overline{\nu}_i = \nu_i$.

2. Confirm that neutrino oscillation violates CP.

To Search for $\not{CP}$ In Oscillation

Look for $P(\bar{\nu}_\alpha \rightarrow \bar{\nu}_\beta) \neq P(\nu_\alpha \rightarrow \nu_\beta)$

" $\bar{\nu}_\alpha \rightarrow \bar{\nu}_\beta$ " is a different process from $\nu_\alpha \rightarrow \nu_\beta$ even when $\bar{\nu}_i = \nu_i$



A Challenge

Genuine $\not{CP}$ and a matter effect both induce a difference between ν and "$\bar{\nu}$" oscillation.

These two effects will have to be disentangled.

Genuine $\not{CP}$ and the matter effect depend quite differently from each other on L (distance) and E (energy).

To disentangle them, one must make oscillation measurements at different L and/or E.