Ramblings, philosophy, advice and neutrino oscillations

John Cummings
Herb Cummings (Dad)

Artist

Science Fiction Fan
KEEP YOUR GUN TRAINED ON HER, MEN! THIS MAY BE ANOTHER STRATEGY?

WHAT ARE THEY TRYING TO DO NOW? LOOKS LIKE THAT HAS A WHIRLING DervISH AT THE CONTROLS!

OR A DIZZY Daffy?

WATCH OUR SMOKE, WILMA! KEEP YOUR EYES PLASTERED TO THAT PORT! YOU'LL HAVE TO GUIDE ME—I'M FLYING BLIND.

IF YOU'RE TRYING TO LAY A SMOKE-Screen IT'S NOT MUCH USE.

NO! WOULDN'T WORK! EARTHSHIP HAS FILTER LENS ON GUN-SIGHTS! SEE RIGHT THROUGH IT! I'M TRYIN' VISIBLE RADIO!

SEE ANYTHING YET, HONEY? ANYTHING THAT MAKES SENSE?

OUR SMOKE TRAIL SEEMS TO BE FORMING LETTERS—BACKWARDS!

THAT'S JUST THE WAY I WANT IT! YOU'RE LOOKING AT IT FROM THE REAR! THE EARTHSHIP WILL SEE IT FROM THE FRONT.

DON'T FIRE FRIENDS!

JUST ANOTHER FLIMSY FRAUD THAT WOULDN'T FOOL A CHILD!

IF THAT TIGER SHIP DOESN'T CRACK IN FIVE MINUTES—SHATTER IT WITH A BROADSIDE!
Observed correlations between angle $\theta_s$ and frequency of scattered electromagnetic waves under certain atmospheric conditions.

*John Cummings*

RPI

**ABSTRACT**

Correlations between the frequency of scattered electromagnetic waves and the scattering angle have been observed in the atmosphere. In addition, conditions displaying such correlations seem to produce also correlations between intensity and scattered angle of the incident waves. We present here data displaying the correlations and evaluate several models to explain them. We consider Mie and Rayleigh scattering of opaque bodies of various sizes and refraction and reflection of the waves by transmissive scattering bodies of various $n$. We determine that a refractive/reflective model describes our data best.

1. **Introduction**

The frequency dependence of scattering angle for electromagnetic waves has been observed in nature for some time, although accurate measurements have only been made recently with the advent of modern detectors. Further exacerbating the difficulty of these measurements is the fleeting nature of their appearance, a point we will return to in section 3.2. Atmospheric conditions can produce or destroy the effect in less than a minute, requiring either dedicated full time observation, or a better understanding of the conditions conducive to the effect (possibly coupled with rapid deployment of equipment.)
Figure 11
Treasure hunt with imaginary numbers.

One two three ... infinity

George Gamow
Support each others stupidity

Don't let professors get away with anything

Physics is not a spectator sport

Follow Wheeler's First Moral Principle
Mixed neutrinos:

\[ |\nu_i\rangle = \sum_\alpha U_{\alpha i} |\nu_\alpha\rangle \]

Maki-Nakagawa-Sakata matrix

\[
U = \begin{bmatrix}
U_{e1} & U_{e2} & U_{e3} \\
U_{\mu1} & U_{\mu2} & U_{\mu3} \\
U_{\tau1} & U_{\tau2} & U_{\tau3}
\end{bmatrix} = \begin{bmatrix}
c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta} \\
-s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta} & s_{23}c_{13} \\
s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta} & c_{23}s_{13}
\end{bmatrix} \begin{bmatrix}
e^{i\alpha_1/2} & 0 & 0 \\
0 & e^{i\alpha_2/2} & 0 \\
0 & 0 & 1
\end{bmatrix},
\]

Probability of changing flavor:

\[
P_{\alpha \to \beta} = |\langle \nu_\beta | \nu_\alpha(t) \rangle|^2 = \left| \sum_i U_{\alpha i}^* U_{\beta i} e^{-i m_i^2 L/2 E} \right|^2.
\]
### Standard Model

#### Particles

<table>
<thead>
<tr>
<th>物 質 粒 子</th>
<th>力を伝える粒子</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>クォーク</strong></td>
<td>強い相互作用</td>
</tr>
<tr>
<td>第1世代</td>
<td>グルーオン</td>
</tr>
<tr>
<td>u</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td></td>
</tr>
<tr>
<td>s</td>
<td></td>
</tr>
<tr>
<td>t</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td></td>
</tr>
<tr>
<td><strong>レプトン</strong></td>
<td>電磁相互作用</td>
</tr>
<tr>
<td>第1世代</td>
<td>光子</td>
</tr>
<tr>
<td>νe</td>
<td></td>
</tr>
<tr>
<td>电子</td>
<td></td>
</tr>
<tr>
<td>νμ</td>
<td></td>
</tr>
<tr>
<td>μニュートリノ</td>
<td></td>
</tr>
<tr>
<td>ντ</td>
<td></td>
</tr>
<tr>
<td>τニュートリノ</td>
<td></td>
</tr>
</tbody>
</table>

19 (+10) parameters  
no gravity

ヒッグ場に伴う粒子（未発見）

H  ?  ?  ...
Oscillation probabilities for an initial electron neutrino
Quantum Mechanics

Wave Picture  ↔  Vector Picture

Diff. Eq.  ↔  Linear Algebra
A Fair Coin

measurement

Tails

Heads

Tails

Heads
\[ v_e = \cos(\theta)v_1 + \sin(\theta)v_2 \]

\[ v_\mu = -\sin(\theta)v_1 + \cos(\theta)v_2 \]
Mixed neutrinos:

\[ |\nu_i\rangle = \sum_{\alpha} U_{\alpha i} |\nu_{\alpha}\rangle \]

**Maki-Nakagawa-Sakata matrix**

\[
U = \begin{bmatrix}
U_{e1} & U_{e2} & U_{e3} \\
U_{\mu1} & U_{\mu2} & U_{\mu3} \\
U_{\tau1} & U_{\tau2} & U_{\tau3}
\end{bmatrix} = \begin{bmatrix}
c_{12}c_{13} & s_{12}c_{13} & c_{13}e^{-i\delta} \\
-s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta} & s_{23}c_{13} \\
-s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta} & c_{23}s_{13}
\end{bmatrix} \begin{bmatrix}
e^{i\alpha_1/2} & 0 & 0 \\
0 & e^{i\alpha_2/2} & 0 \\
0 & 0 & 1
\end{bmatrix},
\]

**Probability of changing flavor:**

\[ P_{\alpha \rightarrow \beta} = |\langle \nu_\beta | \nu_\alpha(t) \rangle|^2 = \left| \sum_i U_{\alpha i}^* U_{\beta i} e^{-i m_i^2 L/2E} \right|^2. \]

\[ P_{\alpha \rightarrow \beta} = \delta_{\alpha \beta} - 4 \sum_{i>j} Re(U_{\alpha i}^* U_{\beta i} U_{\alpha j} U_{\beta j}^*) \sin^2\left(\frac{\Delta m_{ij}^2 L}{4E}\right) \]
\[ + 2 \sum_{i>j} Im(U_{\alpha i}^* U_{\beta i} U_{\alpha j} U_{\beta j}^*) \sin\left(\frac{\Delta m_{ij}^2 L}{2E}\right) \]

\[ s_{ij} = \sin(\theta_{ij}) \]
\[ c_{ij} = \cos(\theta_{ij}) \]
Daya Bay Experiment