POSTDOC RESEARCH EXPERIENCE IN ASIOP AND THE IMPACTS

Guey-Lin Lin

THE YEAR 1991

- 1984 Bachelor degree from NTU physics
- 1984-1986 Serving in Taiwanese army as a 2nd lieutenant
- 1986-1991 PhD study in University of Michigan. Thesis title: “Heavy top effects in the Standard electroweak model”, supervised by Prof. Y.-P. Yao
- Accepted postdoc offer from ASIOP and reported to work on Oct. 3, 1991

THE YEAR 1991

- Work under the NSC proposal of Hai-Yang
- Requested a Mac IIci computer (240k) for doing calculation with SCHOONSHIP—symbolic calculation program invented by M. Veltman.

THE YEAR 1991

- 總統 李登輝
- 行政院長 郝柏村
- 台北市長 黃大洲
- 國科會主委 夏漢民
- 中研院院長 吳大猷
- 物理所所長 鄭天佐

LIFE AS A POSTDOC

- with wife and 2 kids-3 years old and one month old.
- starting salary: 40k NT (36k NT after tax)/month
- 每次領錢 5k
- rent a 3-bed room apartment at 汐止橫科路, 8k/month—map 橫科公園，誠正國中，大坑溪，中研院幼稚園，上班路線。

LIFE AS A POSTDOC

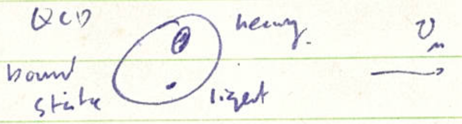
- 每週上班五天半—到週六中午
- 每週三院際電影欣賞
- 每週六下午物理所電影欣賞
- Postdoc 的下班娛樂—Tetris

WORK AS A POSTDOC

- Research topics: heavy quark symmetry and chiral dynamics, effective field theory
- The first presentation on journal club:“On Equivalence Theorem”
- Attending Friday-Saturday lecture series: C. S. Lim, M. Fukugita…
- Participation of international conferences and oversea visits: June-July 1992 attending GEM detector meeting at Texas—visit Tung Mow at Cornell University—visit U. of Michigan; July 1993 attending International Europhysics Conference in High Energy Physics held in Marseille-visit TU Darmstadt.

effective field theory for heavy quarks at low energies
Howard Georgi

Velocity superselection rule



For $p^\mu = m v^\mu$ $p^2 = m^2 = m^2 v_\mu v^\mu$

$\therefore v_\mu v^\mu = 1$

when m is the heavy quark mass, which for large m is essentially the same as the mass of the bound state.

For definiteness, considering the scattering of the heavy quark system by an external potential, into a new state of the same heavy quark, with momentum

$$p^\mu = m v'^\mu + k^\mu$$

In the effective field theory description of the process we will include a different heavy quark field for each velocity.

In other words, our heavy quark field will depend not only on space-time but on v^μ. We will denote this heavy quark field by h_v

let $h_v(x) = e^{imv\cdot x}\psi(x)$ $\therefore \psi(x) = e^{-imv\cdot x} h_v(x)$

Since $(i\not\partial - m)\psi(x) = 0$

中央研究院物理研究所

Chiral Lagrangians - Goldstone bosons

Georgi's book Chap 5.

$SU(3) \times SU(3) \to SU(3)$

look at $SU(2) \times SU(2) \to SU(2)$ first

σ model of Gell-Mann & Levy.

a toy model of nucleon forces and, in particular, of the π-nucleon coupling.

$$\psi = \begin{pmatrix} P \\ N \end{pmatrix}$$

The theory should certainly be invariant under global rotations

$$T_a = \tau_a/2$$

$$\delta\psi = i\epsilon^a T_a \psi$$

If the fermions are massless, the symmetry group is $SU(2) \times SU(2)$, ie

$$\delta\psi_L = i\epsilon^a_L T_a \psi_L$$
$$\delta\psi_R = i\epsilon^a_R T_a \psi_R$$

Let $\epsilon^a = \epsilon^a_R + \epsilon^a_L / 2$

$\epsilon^a_5 = \epsilon^a_R - \epsilon^a_L / 2$

$$\delta\psi = i(\epsilon^a - \gamma_5 \epsilon^a_5) T_a \psi$$

Though $\bar{\psi}\psi$ breaks the Chiral symm. and leaves only isospin.

中央研究院物理研究所

(02) 923- 5162

12/30, 1991.

We now redefine the problem. Chiral dynamics with heavy mesons or baryons.

Minkoski metric

Idea of Jenkins & Manohar:

✓ Baryon Chiral pertu.

UCSD-PTH-91-30 Oct 1991, 26 pages — ask for preprint

Talk, Dobogoko Hungary Aug 1991

Phys Lett B 259. 353-358

Jenkins

UCSD-PTH-91-24

✓ Hyperon nonleptonic decays in Chiral Perturbation — ask for preprint

Baryon masses in Chiral Pertur.

UCSD-PTH-9172

For a heavy baryon, one can write it's momentum as

$$p^\mu = m_B v^\mu + k^\mu$$

$$v.k << m_B$$

The effective theory can be written in terms of baryon field B_v with a velocity v^μ

$$B_v(x) = e^{i m_B \not{v} v_\mu x^\mu} B(x)$$

What does this mean?

"發亞 2F"

錦北100号 上海总会 金龍廳

715-0077 6:00 PM

Let's rewrite the Lagrangian in page 115

$$\mathcal{L}^0_v = i\,\mathrm{Tr}\,\bar\psi_v (v\cdot D)\psi_v + 2g_A\,\mathrm{Tr}\,\bar\psi_v (S_v\cdot A)\psi_v$$

$$+\frac{f_\pi^2}{4}\mathrm{Tr}(\partial^\mu\Sigma^\dagger\partial_\mu\Sigma) + v^3\,\mathrm{Tr}\,M(\Sigma^\dagger+\Sigma)$$

$$-\,i\,\mathrm{Tr}\,\bar R^\mu_v (v\cdot D) R_{v\mu} + 2G_A\,\mathrm{Tr}\,\bar R^\mu_v (S_v\cdot A) R_{v\mu}$$

$$\downarrow$$

$$\cancel{2G_A'\,\mathrm{Tr}\,\bar R^\alpha_v A^\mu v R^\beta_v}$$

$$2G_A'\,\epsilon_{\alpha\beta\mu\nu}\bar R^\alpha A^\beta \gamma^\mu R^\nu_v$$

$$+F_A\,\mathrm{Tr}(\bar R^\mu_v A_\mu \psi_v + \bar\psi_v A_\mu R^\mu_v)$$

$$+i\,\mathrm{Tr}\,\bar\chi_v (v\cdot D)\chi_v + \Delta m\,\bar\chi_v\chi_v$$

$$+2D_1\,\mathrm{Tr}(\bar\psi_v (S_v\cdot A)\chi_v + \bar\chi_v (S_v\cdot A)\psi_v)$$

$$\cancel{+2D_2\,\mathrm{Tr}(\bar R_v (S_v\cdot A)\chi_v - \bar\chi_v (S_v\cdot A) R)}$$

$$+2D_2\,\mathrm{Tr}(\bar R^\mu_v A_\mu \chi_v + \bar\chi_v A_\mu R^\mu_v)$$

For bottom baryons

$$\psi_v = \begin{pmatrix} \Sigma_b^0 & -\sqrt2\,\Sigma_b^+ \\ \sqrt2\,\Sigma_b^- & -\Sigma_b^0 \end{pmatrix} \qquad R^\mu_v = \begin{pmatrix} \Sigma_b^{*0} & -\sqrt2\,\Sigma_b^{*+} \\ \sqrt2\,\Sigma_b^{*-} & -\Sigma_b^{0*} \end{pmatrix}$$

$$\chi_v = \Lambda_b^0$$

From $2g_A\,\mathrm{Tr}\,\bar\psi_v (S_v\cdot A)\psi_v$

$$= 2g_A\,\mathrm{Tr}\Big(\ \bar\Sigma_b^0 \quad\quad -\Sigma_b^0$$

第一屆粒子現象學研討會

The First Workshop on Particle Physics Phenomenology

May 22-24, 1992

Kenting, Taiwan, ROC

FIRST WORKSHOP ON
PARTICLE PHYSICS PHENOMENOLOGY

22-24 May, 1992

Speakers:

Thomas Mannel (Technische Hochschule Darmstadt)

Guey-Lin Lin (Academia Sinica)

Hoi-Lai Yu (Academia Sinica)

Dong-Pil Min (Seoul National University)

Jianwei Qiu (Iowa State University)

C. F. Wai (Academia Sinica)

Y. C. Lin (National Central University)

Waiping Lam (Academia Sinica)

Ka-lok Ng (National Taiwan University)

Heavy Quark Symmetry and Chiral Dynamics in the Meson Sector

(1) Mark B. Wise, Phys Rev D. 45, R2188 (1992)

(2) G. Burdman and John F. Donoghue, UMHEP-365 (1992)

(3). T.-M. Yan, Hai-Yang Cheng, C.-Y. Cheung, G.-L. Lin, Y.-C. Lin, and Hoi-Lai Yu, CLNS 92/1138
IP-ASTP-03-92, to be appeared in Phys. Rev D

0. Motivations and outline:

(1) The strong interaction QCD has spin and flavor symmetry when $M_Q \to \infty$. Mathematically,

$$\mathcal{L}_v^{QCD} = \sum_i \bar{h}_v^i \, i v.D h_v^i + O(\Lambda_{QCD}/M_Q)$$

Here $h_v^i = e^{i M_{Q_i} v.x} Q_i(x)$

Ordinary quark fields in QCD

(2) These symmetries (spin and flavor) were used to analyze weak transition form factors:

$$\langle D(v')| \bar{h}_{v'}^c \gamma_\mu h_v^b |B(v)\rangle = \sqrt{M_B M_D}\, \xi(v.v')(v+v')_\mu$$

$$\langle D^*(v',\epsilon)| \bar{h}_{v'}^c \gamma_\mu h_v^b |B(v)\rangle = i\sqrt{M_B M_D}\, \xi(v.v')\, \epsilon_{\mu\nu\alpha\beta} \times \epsilon^{*\nu} v'^\alpha v^\beta$$

They are related through spin rotations which brings $|D(v)\rangle$ to $|D^*(v,\epsilon)\rangle$ or vice versa

Chiral Dynamics and Heavy Baryon Decays

T.M. Yan, H.Y Cheng, C.Y. Cheung G.L. Lin, Y.C. Lin & H.L. Yu

(1) Motivations and intuitive pictures

(2) The effective Chiral Lag. with Heavy Quark Symmet

(3) Interpolating field methods for the relationship of coupling constants

(4) Quark model determination of the coupling constant

(5) More complex notation

(6) Applications i.e $\Sigma_b \longrightarrow \Lambda_c \pi l \nu$ and the Heavy flavor conserving weak decay $\Xi_c \longrightarrow \Lambda_c$.

(7) Outlook

(1) Motivations and Intuitive pictures

Our basic QCD Lag. is:

$$\mathcal{L}_{QCD} = -\frac{1}{4g^2} G^a_{\mu\nu} G^{a\mu\nu} + \bar{q}(i\not{D} - m_q)q + \bar{Q}(i\not{D} - m_Q)Q$$

where I have seperate light quark q and heavy quark Q

$$m_q = \begin{bmatrix} m_u & & \\ & m_d & \\ & & m_s \end{bmatrix}, \quad m_Q = \begin{bmatrix} m_c & & \\ & m_b & \\ & & m_t \end{bmatrix}$$

The $m_q \to 0$ Chiral limit and the $m_Q \to \infty$ heavy quark limit are vastly different symmetries of QCD and lead to very different physics

(a) The χ symmetries

$\forall N$ massless flavors, $\mathcal{L}_{QCD}$ is inv. under

$$q_L \longrightarrow V_L q_L$$
$$q_R \longrightarrow V_R q_R \qquad , \qquad V_L, V_R \in U(N)$$

Weak-field expansion for processes in a homogeneous background magnetic field

Tzuu-Kang Chyi,[1] Chien-Wen Hwang,[1] W. F. Kao,[1,*] Guey-Lin Lin,[1,†] Kin-Wang Ng,[2] and Jie-Jun Tseng[1]
[1]*Institute of Physics, National Chiao-Tung University, Hsinchu, Taiwan*
[2]*Institute of Physics, Academia Sinica, Taipei, Taiwan*
(Received 15 December 1999; revised manuscript received 25 May 2000; published 20 October 2000)

The weak-field expansion of the charged fermion propagator under a uniform magnetic field is studied. Starting from Schwinger's proper-time representation, we express the charged fermion propagator as an infinite series corresponding to different Landau levels. This infinite series is then reorganized according to the powers of the external field strength B. For illustration, we apply this expansion to $\gamma\rightarrow\nu\bar{\nu}$ and $\nu\rightarrow\nu\gamma$ decays, which involve charged fermions in the internal loop. The leading and subleading magnetic-field effects to the above processes are computed.

PACS number(s): 12.20.Ds, 13.10.+q, 13.40.Hq, 95.30.Cq

I. INTRODUCTION

Particle reactions taking place in the early universe or astrophysical environments are often affected by the background magnetic field or excitations in the medium [1]. A typical example is the modification of the neutrino index of refraction in the early universe or supernova [2]. There one needs to compute the neutrino self-energy in the medium or the background electromagnetic field or both. The neutrino index of refraction is then extracted from the modified dispersion relation of the neutrino. Another example is the plasmon decay $\gamma^*\rightarrow\nu\bar{\nu}$ [1] where the decaying photon acquires an effective mass through the effects of the medium or the background magnetic field. With such an effective mass, the above decay is kinematically permissible. Furthermore, the behavior of electron propagators occurring in the internal loop of the above decay is also affected by the medium or the magnetic field. This also leads to a modification to the plasmon decay amplitude. Finally, a more recent example is the enhancement of neutrino-photon scatterings due to the background magnetic field [3,4]. At the lowest order in the weak interaction, it is known that the amplitude for $\gamma\gamma\rightarrow\nu\bar{\nu}$ is proportional to the neutrino mass [5]. Hence the resulting scattering cross section is rather suppressed. On the other hand, the presence of the background magnetic field alters the structures of internal electron propagators, such that $\gamma\gamma\rightarrow\nu\bar{\nu}$ is non-vanishing at $O(G_F)$ even in the massless limit of neutrinos. Specifically, the $\gamma\gamma\rightarrow\nu\bar{\nu}$ cross section is enhanced by a factor $(m_W/m)^4(B/B_c)^2$ due to a background magnetic field B [3,4], where m_W and m are the masses of W boson and electron respectively; $B_c\equiv m^2/e$ is the critical magnetic field.

In the above processes, the relevant magnetic-field strengths are often smaller than the critical value B_c. Therefore it is appropriate to expand the decay width, cross section or other physical quantities in powers of B/B_c. In the literature, such an expansion is usually performed after the relevant amplitude is obtained [6]. For a more complicated process, it is not always convenient to do so since the amplitude to be expanded may be very cumbersome. In this article, we shall propose a more straightforward weak-field expansion, which is performed directly on the charged fermion propagator participating in the process. With the charged fermion propagators expanded, the physical amplitude can be easily expressed in powers of B/B_c. To perform such an expansion on propagators, we shall begin with Schwinger's proper-time representation for a charged fermion propagator under a uniform background magnetic field [7]. It is useful to realize that Schwinger's representation can be recast into a series expansion in terms of Landau levels [8]. In the weak field limit $B\ll B_c$, we shall demonstrate that one can reorganize the infinite series in powers of the field strength B. This is the expansion we are after.

This article is organized as follows: In Sec. II, we will review Schwinger's derivation of charged fermion propagator in a homogeneous background magnetic field. Since the convention used by Schwinger differs from the currently popular convention, we shall repeat some relevant details of the derivation for clarification. We shall also illustrate how to rewrite Schwinger's result as an infinite series where each term is associated with specific Landau levels [8]. In the weak-field limit, we shall demonstrate how to rearrange the above series in powers of the magnetic-field strength B. Finally, some technical issues relevant to the phase factor in Schwinger's proper-time representation will be discussed in this section. In Sec. III, we begin with a brief discussion on our earlier work [4], where the weak-field expansion technique is applied to $\gamma\gamma\rightarrow\nu\bar{\nu}$ and its crossed processes in a background magnetic field [3,9]. To further illustrate the technique of weak-field expansion, we also calculate the decay rates of $\gamma\rightarrow\nu\bar{\nu}$ and the neutrino Cherenkov process $\nu\rightarrow\nu\gamma$ in a background magnetic field. Our results will be compared to previous calculations which are performed using exact charged-fermion propagators in the background magnetic field [10–12]. A few concluding remarks are presented in Sec. IV.

II. CHARGED-FERMION PROPAGATOR IN A HOMOGENEOUS BACKGROUND MAGNETIC FIELD

A. The exact propagator solution

The Green's function $G(x,x')$ of the Dirac field in the presence of a gauge field A_μ satisfies the following equation:

*Email address: wfgore@cc.nctu.edu.tw
†Email address: glin@cc.nctu.edu.tw

Energy spectrum of tau leptons induced by the high energy Earth-skimming neutrinos

Jie-Jun Tseng,[1,*] Tsung-Wen Yeh,[2,†] H. Athar,[2,3,‡] M. A. Huang,[4,§] Fei-Fain Lee,[2,∥] and Guey-Lin Lin[2,¶]
[1]*Institute of Physics, Academia Sinica, Taipei 115, Taiwan*
[2]*Institute of Physics, National Chiao-Tung University, Hsinchu 300, Taiwan*
[3]*Physics Division, National Center for Theoretical Sciences, Hsinchu 300, Taiwan*
[4]*Department of Physics, National Taiwan University, Taipei 10617, Taiwan*
(Received 28 May 2003; published 26 September 2003)

We present a semianalytic calculation of the tau-lepton flux emerging from the Earth induced by incident high energy neutrinos interacting inside the Earth for $10^5 \leqslant E_\nu/\mathrm{GeV} \leqslant 10^{10}$. We obtain results for the energy dependence of the tau-lepton flux coming from the Earth-skimming neutrinos, because of the neutrino-nucleon charged-current scattering as well as the resonant $\bar{\nu}_e e^-$ scattering. We illustrate our results for several anticipated high energy astrophysical neutrino sources such as the active galactic nuclei, the gamma-ray bursts, and the Greisen-Zatsepin-Kuzmin neutrino fluxes. The tau-lepton fluxes resulting from rock-skimming and ocean-skimming neutrinos are compared. Such comparisons can render useful information about the spectral indices of incident neutrino fluxes.

DOI: 10.1103/PhysRevD.68.063003 PACS number(s): 95.85.Ry, 14.60.Fg, 14.60.Pq, 95.55.Vj

I. INTRODUCTION

The detection of high energy neutrinos ($E_\nu > 10^5$ GeV) is crucial to identify the extreme energy sources in the Universe and possibly to unveil the puzzle of cosmic rays with energy above the Greisen-Zatsepin-Kuzmin (GZK) cutoff [1]. These proposed scientific aims are well beyond the scope of conventional high energy gamma-ray astronomy. Because of the expected small flux of the high energy neutrinos, large scale detectors ($\geqslant 1$ km^2) seem to be needed to obtain the first evidence.

There are two different strategies to detect the footprints of high energy neutrinos. The first strategy is implemented by installing detectors in a large volume of ice or water where most of the scatterings between the candidate neutrinos and nucleons occur essentially inside the detector, whereas the second strategy aims at detecting the air showers caused by the charged leptons produced by the neutrino-nucleon scatterings taking place inside the Earth or in the air, far away from the instrumented volume of the detector. The latter strategy thus includes the possibility of detection of quasihorizontal incident neutrinos, which are also referred to as Earth-skimming neutrinos. These neutrinos are considered to interact below the horizon of an Earth based surface detector.

The second strategy has been proposed only recently [2]. The Pierre Auger observatory group has simulated the anticipated detection of the air showers from the decays of τ leptons [3]. The tau air shower event rates resulting from the Earth-skimming tau neutrinos for different high energy neutrino telescopes are given in [4]. A Monte Carlo study of the tau air shower event rate was also reported not long ago [5]. We note that Ref. [4] does not consider the tau-lepton energy distribution in the ν_τ-nucleon scattering, and only the incident tau neutrinos with energies greater than 10^8 GeV are considered. For Ref. [5], we note that only the sum of tau air shower event rates arising from different directions is given. Hence some of the events may be due to tau-leptons or neutrinos traversing a large distance. As a result, it is not possible to identify the source of the tau-neutrino flux even with the observation of the tau-lepton induced air shower.

In this work, we shall focus on high energy Earth-skimming neutrinos and shall calculate the energy spectrum of their induced tau leptons, taking into account the *inelasticity* of neutrino-nucleon scatterings and the tau-lepton *energy loss* in detail. Our work differs from Ref. [5] in our emphasis on the Earth-skimming neutrinos. We shall present our results in the form of outgoing tau-lepton spectra for different distances inside the rock, instead of integrating the energy spectra. As will be demonstrated, such spectra are insensitive to the distances traversed by the Earth-skimming ν_τ and τ. They are essentially determined by the tau-lepton range. Because of this characteristic feature, our results are useful for setting up simulations with specifically chosen air shower content detection strategy, such as detection of the Cherenkov radiation or the air fluorescence. Our results are also beneficial for the coherent Cherenkov radio emission measurement detectors such as the Radio Ice Cherenkov Experiment (RICE) [6] and the upcoming Antarctic Impulsive Transient Array (ANITA) [7].

We start with our semianalytic description in Sec. II. The transport equations governing the evolutions of neutrino and tau-lepton fluxes will be derived. Using these, we then calculate the tau-lepton flux resulting from the resonant $\bar{\nu}_e e^- \to W^- \to \bar{\nu}_\tau \tau^-$ scattering. In Sec. III, we summarize our main results, namely, the tau-lepton energy spectra due to neutrino-nucleon scatterings. The implications of our results will be discussed here also. In particular, we shall point out

*Email address: gen@phys.sinica.edu.tw
†Email address: twyeh@cc.nctu.edu.tw
‡Email address: athar@phys.cts.nthu.edu.tw
§Present address: National United University, Miaoli 360, Taiwan. Email address: huangmh@phys.ntu.edu.tw
∥Email address: u8727515@cc.nctu.edu.tw
¶Email address: glin@cc.nctu.edu.tw

WHAT I LEARN FROM THESE POSTDOC YEARS?

- Explore the frontier and extend the research scope
- Fun with research!

CALT-68-1721
DOE RESEARCH AND
DEVELOPMENT REPORT

New Symmetries of the Strong Interaction*

Mark B. Wise

California Institute of Technology, Pasadena, CA 91125

Lectures presented at the Lake Louise Winter Institute
February 17-23, 1991

Abstract

New symmetries of the strong interactions appear in heavy quark physics. They are used to predict many properties of hadrons containing a single heavy quark. Some of these predictions are expected to play an important role in determining the values of elements of the Cabibbo–Kobayashi–Maskawa matrix.

* Work supported in part by the U.S. Dept. of Energy under Contract no. DEAC-03-81ER40050.

1. INTRODUCTION

Over the past few years remarkable progress has been achieved in our ability to compute properties of hadrons containing a single heavy quark Q[1-10] (i.e., a quark with mass, m_Q, much greater than the scale of the strong interactions Λ_{QCD}). The strong interaction physics of such hadrons is basically nonperturbative with the light degrees of freedom (i.e., light quarks, anti-quarks and gluons) typically having four-momenta small compared with the heavy quark mass. In such a situation it is appropriate to go over to an effective theory, where the heavy quark mass goes to infinity, with its four-velocity fixed.[6,8] In the effective theory the strong interactions of the heavy quark are independent of its mass and spin. Consequently, for N heavy quarks (perhaps with very different masses) the effective theory has a SU(2N) spin-flavor symmetry,[6,8] which can be used to predict many properties of hadrons containing a single heavy quark.

The effective heavy quark theory is similar to an approximation often used in classical mechanics. When a baseball is thrown it churns up the air in its path, but the air has a negligible impact on the baseball's path. Typically we just neglect the air and say that the ball falls under the influence of gravity in a way described by Newton's laws. The heavy quark is analogous to the baseball and the light quarks, antiquarks and gluons are analogous to the air. However, even though the heavy quark mass is taken to infinity, it is still treated as negligible compared with the Planck mass. Consequently, the heavy quark path is a straight worldline described by a four-velocity v^μ satisfying $v^2 = 1$. There is another similarity between the heavy quark effective theory and the classical physics of a baseball; pair creation of heavy quark antiquark pairs doesn't occur in the effective theory.

The SU(2N) spin-flavor symmetry of the heavy quark effective theory is not manifest in the full theory of QCD; it only becomes apparent in the effective theory where the heavy quark masses are taken to infinity. This situation is familiar from our experience with the light quark flavor symmetries of QCD. The strong interactions of light quarks, q, (with masses, m_q, that are much less than the QCD scale) is greatly sim-