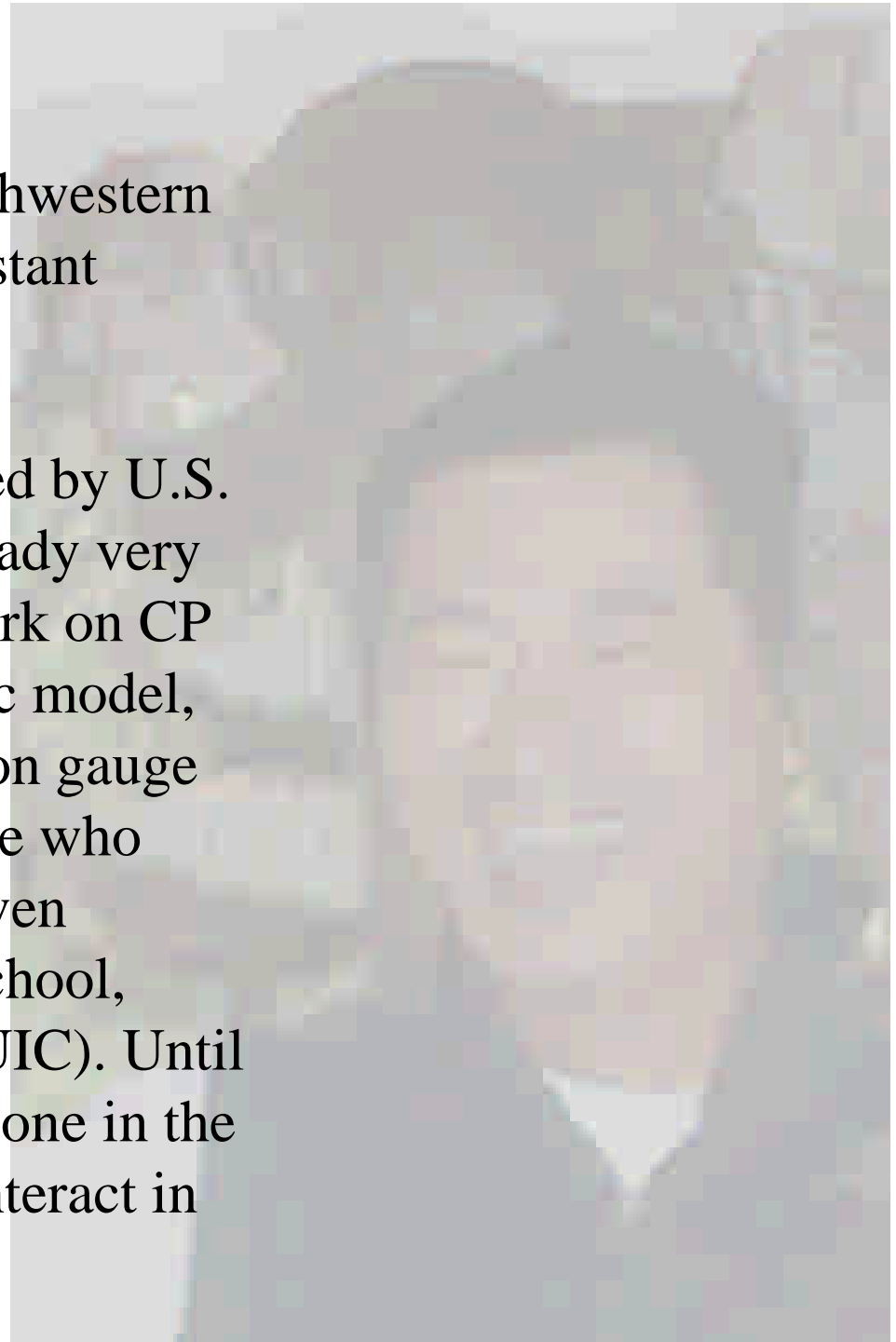


In memory of Darwin (張達文)

When Darwin Chang came to Northwestern University in 1986 as a young assistant professor with the prestigious OUTSTANDING JUNIOR INVESTIGATOR AWARD granted by U.S. Department of Energy, he was already very well recognized for his seminal work on CP violation in the left-right symmetric model, as well as many insightful studies on gauge theories. I believe that I was the one who benefited most from his coming, even though I was working in another school, University of Illinois at Chicago (UIC). Until then, I had been eager to find someone in the Chicago area with whom I could interact in physics research.



Soon after Darwin's arrival, I was deeply impressed by his passion in physics and his energy in research. He was very down-to-earth but knowledgeable, open and honest but critical in discussions. I learned a great deal from him. We developed a mutual bond and began to meet regularly at Fermilab, Northwestern, and UIC.

Throughout the world, Darwin had many physics friends and collaborators. Some of them were not known to me before and later became mine. It greatly enhanced my research network. Following is a partial chronological list of work in which Darwin and I were involved. The list also shows a roster of participating collaborators, who were close to Darwin.



We warmed up our collaboration first on
ANOMALY INDUCED AMPLITUDES OF NEW GAUGE BOSONS
with Shih-Chang Lee (李世昌) who visited
Fermilab in 1987. Our result would be useful
for Z' search at the LHC.



In 1988, teaming up with Palash Pal, one of
Darwin's close fellow classmate at Carnegie-
Mellon, Darwin and I worked on

*SPONTANEOUS LEPTON NUMBER BREAKING
AT ELECTROWEAK SCALE*

Phys. Rev. Lett. **61**, 2420(1988)

In 1989, Darwin and I worked on

***CONSTRAINTS ON MUONIUM -
ANTI-MUONIUM CONVERSION***

Phys. Rev. Lett. **62**, 2583 (1989)

It might be the first in-depth study about the muonium-anti-muonium conversion with other precision measurements from the viewpoint of modern gauge theories.

When Tzu-Chiang Yuan came to Chicago in 1989, we set up the correct Renormalization Group analysis due to the dim-6 and dim-8 operators on the neutron electric dipole moment.

***THE CHROMOELECTRIC DIPOLE MOMENT OF THE HEAVY QUARK
AND PURELY GLUONIC CP VIOLATING OPERATORS***

Phys. Rev. Lett. **68**, 439 (1992)



Although I knew Goran Senjanovic when we were in Brookhaven in the early 80, it was Darwin's close friendship with Goran that brought us together again to work on

NEUTRINO MAGNETIC MOMENT AND THE DICYCLIC GROUP

Phys. Rev. Lett. **67**, 953 (1991)

and subsequent work. Our study may be the first application of the non-abelian discrete group in the flavor physics.



While I was at CERN in 1992, through Darwin's connection, George W.S. Hou (侯維恕) collaborated with us on

*TWO LOOP CONTRIBUTIONS OF FLAVOR CHANGING
NEUTRAL HIGGS BOSONS TO $\mu \rightarrow e \gamma$*



After Darwin came back to Taiwan, I have had chances to work with physicists in Taiwan, like Vincent Chia-Hung Chang (張嘉泓) and others. For example, in 1999, Chia-Hung, Darwin and I worked out details on

*VECTOR QUARK MODEL and
 $b \rightarrow X_s \gamma$ DECAY*

Darwin's favorite subject was always the origin of CP violation. His persistent curiosity on this issue shaped our work on

A SCHEME FOR RADIATIVE CP VIOLATION

Phys. Rev. Lett. 74, 1928 (1995)

and

*A SIMPLE CHARGED HIGGS MODEL OF
SOFT CP VIOLATION WITHOUT
FLAVOR CHANGING NEUTRAL CURRENTS*

Phys. Rev. Lett. 81, 2028 (1998)



In 1998, Darwin spent a summer month at Fermilab at the same time as Apostolos Pilaftsis, a young theorist with expertise in CP violation of SUSY, was also visiting there. We worked together and discovered something interesting on

***NEW TWO LOOP CONTRIBUTION TO ELECTRIC DIPOLE MOMENT
IN SUPERSYMMETRIC THEORIES***

Phy. Rev. Lett. **82**, 900 (1999)

The paper has received a large number of citations because it gives the most stringent CP constraint on the not-yet observed SUSY particles.



Darwin looked after his graduate students very well. Through Darwin, I had the opportunity to work with those bright and young minds, like We-Fu Chang (張維甫), Chen-Pin Yep, and Chung-Hsien Chou (周忠憲).

***LARGE TWO LOOP CONTRIBUTIONS TO $g-2$ FROM A GENERIC
PSEUDOSCALAR BOSON
NAMBU-GOLDSTONE BOSONS IN CP VIOLATING THEORY WITH
MAJORANA MASSES***

Above is only a sample of his work in which I was involved. Darwin has done other important research in high energy particle physics with people named above as well as with Barr, Ma, Masiero, Mohapatra, Murayama, Pakvasa, and Zee (徐一鴻) etc.



In addition, I admire Darwin's unusual broad research coverage in condensed matter physics and other areas.

Curiosity can be the key word in describing Darwin's life. It drove him into scientific research but also into other activities. I remember when we were hiking near Banff, Canada, we came to a narrow valley surrounded by cliffs with a mysterious vortical air flow. Darwin was so excited that he decided to climb up the steep cliff and spread leaves into the valley to study the air stream.



I know Darwin took teaching very seriously. Before each class he always worked out all technical details, and on many occasions he found some not-so-noticeable fine points. For example, while teaching statistical mechanics, he was deeply puzzled by the apparent equality of the odd-state-sum and the even-state-sum of the partition function of a 3-D rotator in the high temperature expansion, but not in the low temperature. We, with Hsiu-Hau Lin (林秀豪), came to some understanding of this mystery.

* Michelson - Morley

$$\sum_{l=0}^{\text{even} \dots \infty} (2l+1) \exp[-\beta l(l+1)] \stackrel{?}{=} \sum_{l=1}^{\text{odd} \dots \infty} (2l+1) \exp[-\beta l(l+1)]$$

$$\stackrel{?}{=} \frac{1}{2\beta} + \frac{1}{6} + \frac{\beta}{30} + \frac{2\beta^2}{315} + \frac{\beta^3}{630} + \frac{2\beta^4}{3465} + \frac{191\beta^5}{675675} + \dots$$

$$t_2 = \frac{l_2}{c+v} + \frac{l_2}{c-u}$$

$$= \frac{2l_2}{c(1 - \frac{v^2}{c^2})}$$

$$t_1 = \frac{2l_1}{c \sqrt{1 - \frac{v^2}{c^2}}}$$

$$u = \sqrt{c^2 - v^2}$$



Darwin was a citizen of conscience. During the tumultuous period of the student movement in Beijing 1989, Darwin paid a great deal of attention to its development. He voiced his democracy viewpoint to his colleagues and friends, and to physics communities and beyond. After June 4, he was frustrated, and on occasions he expressed his protest against authoritarianism by wearing the T-shirt bearing the infamous image of the lone protester against the fully-loaded tank.

Darwin opened his home for visitors and I was his guests on many occasions when he lived in the Chicago area, in the Bay area, and in Hsinchu. Sometimes, it was just a meal, and sometimes it was lodging. So I got to know his family very well, and I know that Darwin loved his family very much. Darwin was a good husband and a good father.

I started writing this note with sadness, but I gradually became thankful and grateful for the opportunity to work with this exceptional scientist. He was my closest friend, a collaborator, and on many occasions my physics teacher even though he was younger. I sincerely express my greatest respect to Darwin Chang and celebrate his contributions to physics and education.

