The Photon:

# Spotlight

Physics Alumni | UM Physics Research

## *On Alumna Adeena Mignogna*

I believe I am one of maybe two or three people out of a hundred on my project to come here with a background in Physics. This, combined with the fact that I've been out of school for less than three years, has put me in a unique position as someone who knows and remembers enough of that stuff to be put to work as lead of our Flight Dynamics System.

I currently work for Orbital Sciences Corporation in Germantown, MD. Our main business is building rockets and satellite systems. The two spacecraft I work on, OrbView-3 and OrbView-4 , which are both set to launch sometime next year, require high-precision knowledge and control of their orbits. This is PHYS 410 (Theoretical Newtonian Dynamics) without the "Theoretical" part and with the addition of a few forces such drag, solar radiation pressure, etc.

This is not my first job since graduating from UMCP, but it is the first job I've had that directly uses some of the physics I've learned. Straight out of school, I worked in Satellite Operations for AlliedSignal at Goddard Space Flight Center. I got the job based on my background in Physics (they figured I was smart), and based on the experience I had working with the Space Physics Group run by Dr. Glenn Mason designing and building spaceflight instrumentation. Specifically, I helped to design an instrument called Ultra Low Energy Isotope Spectrometer (ULEIS) that's on the Advanced Composition Explorer (ACE) spacecraft.

The job with AlliedSignal was a shot in the dark - I didn't realize until very late in my last year at the University of Maryland that I wanted to work rather than attend graduate school. At the time, I felt very lucky to have found a job at all.

I absorbed a lot of knowledge about spacecraft and the different spacecraft subsystems at Goddard that eventually led

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*On Particle Physics*

## *Finding the origin of CP violation with the bottom quark*

Studying the symmetries of nature and how they are broken are age-old physics issues and have been some of the most important topics on the particle physics agenda. This is exactly what two new high energy physics experiments are about to investigate using decays of B mesons - mesons where one of the constituent quarks is a b quark. These experiments are being carried out using the newly commissioned particle accelerators dedicated to high rate production of B mesons - the so-called B factories - at the KEK laboratory in Japan (the Belle experiment) and at the Stanford Linear Accelerator Center (SLAC) (the BaBar Experiment).

### The Maryland Program

High energy physicists from University of Maryland have been working on the design and construction of the BaBar particle detector since 1993, and are now busy with the data taking and physics analysis of the experiment. The Maryland group members are the UM faculty Prof. Hassan Jawahery and Prof. Douglas Roberts, research staff Dr. Carlo Dallapiccola, Dr. Douglas Fong, Dr. James Olsen and Dr. Jochen Schieck, graduate students Amir Farbin and Vincent Lillard, and electronics engineer Mr. Robert Bard.

### The Story of CP Symmetry

CP refers to a combination of two symmetries, P symmetry (for Parity) and C symmetry (for Charge conjugation). P symmetry requires that a left-handed form of

### Q & A

**What is CP?**
CP is the combination of two symmetries - P symmetry (Parity symmetry) and C symmetry (Charge conjugation symmetry).

**So, basically, what is P symmetry?**
As its name indicates, P symmetry (Parity symmetry), is respected when the mirror image of a reaction occurs at the same rate as the original reaction. At one point, scientists thought all reactions demonstrated P symmetry.

**C symmetry?**
C symmetry (Charge conjugation symmetry) is respected when a reaction remains unchanged after all particles are replaced with their anti-particles.

**Why combine C and P symmetries?**
In the 1950's, scientists found an exception to P symmetry. Studies on radioactive reactions revealed that some reactions do not demonstrate P symmetry or, as the analogy goes, some reactions did not occur as often as their mirror image. But, scientists also discovered that they could restore symmetry to the reactions by replacing the particles within these reactions with their anti-particles (C symmetry). In other words, this combination of C symmetry with P symmetry (CP symmetry) restores symmetry to reactions

a reaction is equally probable as its right-handed form, and C symmetry (for Charge conjugation) requires equality between two processes where the particles are replaced with their anti-particle counterparts. As an example of P symmetry in a left-right symmetric nature, a reaction such as decay of a negative muon (a heavier version of electron) would equally likely produce a clockwise spinning electron (left-handed) and a counter-clockwise spinning electron (right-handed).

Studies of radioactive reactions, as well as muon decays, in the 1950's established that these equalities are not respected in these processes, hence, left-right symmetry is broken. However, it turns out that the equality is restored if the particles are replaced with their anti-particles; that is, the combined symmetry CP is fine. This was believed to be the case until the observation by Cronin and Fitch in 1964 that the K0L meson, which was expected to be a purely CP odd mixture of K0 and anti-K0 mesons, sometimes (two in a thousand) decays into a CP even pair such as P+P- or P0P0. This provided clear evidence that CP symmetry is broken.

Cronin and Fitch were awarded the Nobel Prize in physics in 1980 for this discovery. Unfortunately, since then we have not learned much about CP violation. Kaon mesons remain the only system that show any evidence for CP violation. Moreover, the origin of this effect has yet to be determined.

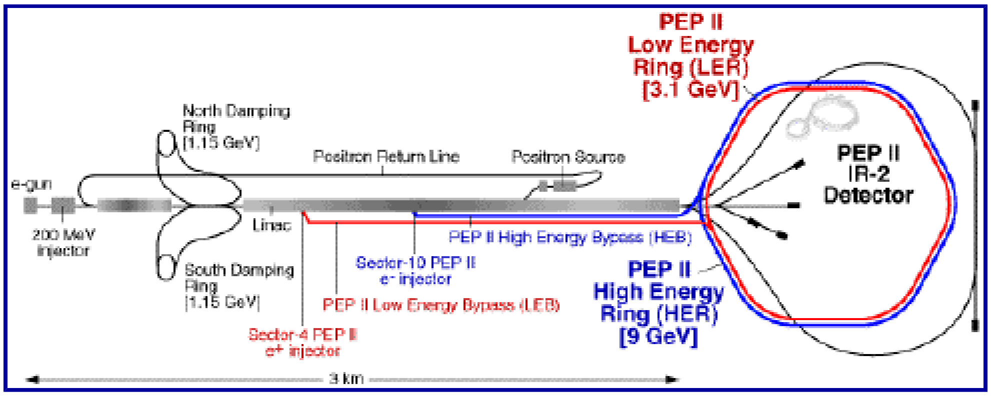
One of the initial theoretical hypotheses attributed the effect to a new super-weak force which is responsible for mixing of the degenerate neutral kaon states, K0 and K0. Recently, experiments at CERN and Fermi lab showed convincing evidence for direct CP violation in the decay process, which essentially rules out the superweak hypothesis as the only source of CP violation.

*(Click on the image below for an expanded, animated view. WARNING: the animation is a 2 MB GIF... it may take a long time to download.)*

without P symmetry.

**Here we go again...**
As mentioned above, scientists discovered that P symmetry could be broken but also thought that this symmetry could be restored with the combined CP symmetry. Then in 1964, Cronin and Fitch provided clear evidence that CP symmetry could be broken, too. Not only did this observation win the two scientists the 1980 Nobel Prize, it also posed a new challenge for scientists - where did this violation of symmetry come from?

University of Maryland physicists in the BaBar experiment are working to understand the origin of CP symmetry violation by studying decay reactions of B mesons.



*A schematic of the B factory at SLAC, where the electron and positron beams are traced in the linear accelerator up to the collision in the BaBar detector at the interaction area (IR-2).*

The leading theoretical explanation in the standard model attributes the breaking of CP symmetry to the way that three generations of quarks get misaligned in the weak interactions. This mixing of quarks is described by a 3x3 unitary matrix known as the Cabbibo-Kobayashi-Maskawa (CKM) matrix, which contains 3 real angles and one complex phase - the complex phase is the source of CP violating effects.

The primary aim of the BaBar experiment is to determine, by studying the decays of B mesons, if the CKM matrix contains a complex phase. The B meson system is analogous to the kaon system where the strange quark is replaced by the b quark. However, because the b quark is much heavier than the strange quark, theoretical calculations of the properties of the B system are more reliable than in the kaon system.

**Cosmology**
Interest in the origin of CP violation also has cosmological significance. It is crucial to understanding matter anti-matter asymmetry in nature. CP violation is one of the ingredients in the explanation of how a matter - anti-matter symmetric early universe ends up in a matter-dominated situation. In other words, it's a part of why we exist!

**Where are we on the experimental front?**
The design and construction of the B factory and the BaBar experiment started in the early 1990's. After a competition between Cornell and SLAC, SLAC's site was selected for the construction of the accelerator and the experiment. The machine is designed to accelerate beams of electrons (at energy of about 9 GeV) and positrons (at energy of 3.5 GeV) in separate rings and collide them at a center of mass energy near the peak of the Y(4s) resonance which decays predominantly into a pair of B mesons (see the animation on the front page). The beam energies are chosen unequal in order to provide a boost to the center-of-mass frame, which in turn allows the B mesons to travel an average distance of 250 micro-meters apart before decaying.

Another requirement for the machine is to deliver a high rate of B mesons - approximately 30 million B meson pairs per year. This requires storing thousands of bunches of electrons and positrons in the accelerator ring- each ring at an electric current of nearly 1 Amp.

The BaBar detector is designed to detect and record the products of the B meson decays, which are then used to study its decay properties and the time evolution of its decay process. It is this ability to determine the time evolution of the decay process which is expected to provide a theoretically clean measurement of CP violation in B meson decays.

The BaBar experiment has been operating since May of 1999. The accelerator intensity is already within a factor of two of the design intensity. The experimenters are busy calibrating the detector. At this rate of data taking, the first signs of new physics could be out by summer of 2000! Stay tuned!

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*OrbView-3 Satellite Illustration Courtesy of Orbital Imaging Corporation (ORBIMAGE).*

me here to Orbital. Based on the knowledge I gained at Goddard, I was hired to code in C++ on the Mission Planning System (MPS) for the OrbView-3 and OrbView-4 satellites. We're developing detailed models of the different spacecraft subsystems that allow the MPS to "task" the spacecraft or, in other words, to allocate resources and use the spacecraft in a safe and efficient fashion.

After a few short months, my responsibility at Orbital grew to include the Flight Dynamics System (FDS) and anything dealing with the orbit of these two spacecraft. The FDS predicts the orbit of the spacecraft, generates various reports (when the spacecraft will be in eclipse, etc.) and allows the operators to plan orbit adjustments. My task is to use pre-existing, off-the-shelf software products and integrate them to create a working FDS that interfaces with other systems, like the MPS.

My entire life, I've been using and programming computers, and I always knew I would use them extensively at work. However, I never imagined that I would ever be labeled a "Software Engineer." But even though the MPS and the FDS are software systems, my background in physics and engineering are the base of knowledge that I use every day.

Several years ago, as an exercise from a self-development workbook I had, I wrote down some goals. The most important one was that I work in the space industry. Well, here I am. Any other background, such as a degree in engineering, might not have led me down the same path.

What happens next? After these two spacecraft launch, I'm not sure. But given my background in physics and my work history, I think I'll have the option to take on tasks that are based more on what I want to be doing than anything else.

• See Adeena's profile

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