Alfonso Albano:

A Distinguished Scientist in Measures of Non-linear Dynamics and An Exemplary Educator

by Manuela Tarroja-Keller

Professor Alfonso M. Albano, 'Al' to family, colleagues, friends and students alike, is a distinguished scientist, an exemplary teacher and an outstanding mentor.

Al's research experience comprised early work on mathematical physics and non-equilibrium thermodynamics resulting in papers co-authored with distinguished scientists, such as Max Dresden and Peter Mazur. He later branched out to work on the characterization of nonlinear dynamics and complex systems in physical and biological systems. His outstanding work in this field earned him appointments to national committees and editorial boards of professional journals.

His contributions to Bryn Mawr College, a liberal arts school for women in Pennsylvania where he had served as a faculty member since 1970, are many. As a popular professor, he is known for his patience, humor and ability to communicate. His efforts and the contributions of the faculty in the physics department made Bryn Mawr College a leading college for educating women undergraduates who major in physics, earning the department the (US) Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring in 1996. See Figure 1. He mentored numerous undergraduate and graduate students until his retirement from Bryn Mawr and now lends his scientific knowledge to support the development of science in academic institutions in the Philippines.

ACADEMIC AND PROFESSIONAL APPOINTMENTS

Al obtained his Bachelor of Science degree in Physics from the University of the Philippines in 1959. He taught in the Department of Physics of his Alma Mater for two years before he went to the US to earn a Master of Science degree in Physics from the University of Iowa in 1964. He then pursued doctoral studies under the tutelage of Max Dresden at the State University of New York at Stony Brook obtaining his Ph. D. in Physics in 1969. After teaching at Stony Brook for a year, he moved to Pennsylvania to assume a Lecturer position at Bryn Mawr College. As his academic career flourished in Bryn Mawr, he moved up the ranks, becoming the Marion Reilly Professor in 1989. His calm disposition and administrative skills landed him college appointments such as Chairman of the Physics Department from 1980 – 1984 and Acting Dean of the Graduate School of Arts and Sciences. Now retired, Al remains the Marion Reilly Professor Emeritus and a Research Professor at Bryn Mawr.

His exemplary research on chaos and nonlinear dynamics earned him appointments to various national committees such as the National Institute of Mental Health's Committees on Cognitive Functional Neuroscience and the Review Committee

Figure 1. Alfonso Albano with former US President Clinton, receiving the Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring in 1996.

for Computational Neuroscience (USA) and editorial boards of professional journals such as Physica D and Physical Review E. In 1996, he served as a consultant for the United Nations Development Programme (UNDP) at the Centre for Fluid Dynamics, University of the Philippines Los Baños and University of the Philippines Baguio. His most recent appointment was as a member of the Science Advisory Board of the Blast Lethality and Injury Program of the Uniformed Services University of the Health Sciences (USA).

RESEARCH ON MEASURES OF NONLINEAR SYSTEMS

Al's nonlinear dynamics expertise is strongly anchored on his earlier research on non-equilibrium thermodynamics and nonlinear systems at the Lorentz Institute for Theoretical Physics, University of Leiden in the Netherlands. In the 1980s, he began collaborative research with students and colleagues on correlation dimensions of nonlinear systems and predicting the onset of chaos. From lasers and bouncing balls, his research expanded to determining nonlinear behavior of signals generated from neurons, the human heart, the human brain, medicinal leech and monkeys.

Complex behavior in physical as well as biological systems has been initially associated with random statistical occurrences. In 1961, Lorenz in his numerical study suggested that the weather behavior has a sensitive dependence on initial conditions. This phenomenon is now known as the 'butterfly effect', one that is associated with 'chaos'. The temporal behavior of such a system may appear to be random. However, since a chaotic system is deterministic, there are patterns that can be discernible, as in the Lorenz attractor. If a nonlinear system is accurately modeled, then predicting its behavior would be simple. Most nonlinear systems, however, are not sufficiently known to be able to describe their behavior by a set of equations. Predictability in most nonlinear systems, if indeed they are, will depend on quantifiable measures based on the temporal recordings of signals.

Measuring Chaos in Lasers

A common measure of chaos is the correlation dimension. The calculation is based solely on a time series from which a system's trajectory is reconstructed in an 'embedding space' using `the method of time delays. While the approach seemed simple, getting an accurate value of the correlation dimension was not. Al developed an algorithm that improved on the Grassberger and Procaccia method for evaluating the correlation dimension. Al applied singular value decomposition and used the results to ascertain chaotic behavior in unstable laser systems (Albano et al. 1988).

Characterizing Nonlinear Behavior in Biological Systems

From his initial work with lasers, Al branched out and has become a key contributor to the dynamical characterization of biological systems, developing or adapting algorithms to characterize the nonlinear behavior of those systems (see, for example, Albano et al. 2008). Among these are:

1) Time-Resolved Statistics. In this approach, statistical quantities such as the mean, variance and kurtosis are calculated at successive windows of time referred to as 'epochs'. The approach was applied to analyze the behavior of a medicinal leech when an interneuron of one of the leech brains is electrically stimulated. The time series and the corresponding time-resolved statistics of the electrical signals along the ventral nerve cord before, during and after the stimulation were monitored for leeches that were not moving, crawling, or swimming prior to the stimulation. The time-resolved statistics showed dramatic differences in post stimulation behavior among the three sets of leeches. The approach can support or contradict existing ideas in behavioral patterns. In the case of the medicinal leech, the results support the concept that the eventual response depends

on the behavior of the animal before the stimulus.

2) Power Spectral Density. From a time series, a discrete Fourier transform can be calculated from which the power spectral density (PSD) can be determined. If the artifacts (edge effects and aliasing) of PSD calculation are removed, PSD accurately shows the strength of the signals as a function of frequency. PSD was used by Al and his collaborators to analyze the spontaneous rhythmic oscillation of the blood flow from the dorsum of the foot of anesthetized normal, pre-diabetic and diabetic monkeys. The PSDs of the flow rate data showed that, as the metabolic state changes from normal to pre-diabetic to diabetic, the dominant peaks move to lower frequencies. Since derangement of vasomotion may be a possible cause of diabetic neuropathy, this research has a potential use in early diagnosis of diabetes.

Figure 2. Al with wife, Connie, and participants of the 2008 MSU-IIT workshop.

3) Mutual Information and Transfer Entropy. Mutual information is a measure of the amount of nonlinear correlations between data streams and transfer entropy is a measure of the amount of information transferred between them. These two measures were used to compare the EEG (electroencephalographic) signals from human subjects at different locations in the scalp when eyes are open and eyes are closed. The results suggest dramatic differences in these two scenarios.

Al is continuing his research on these and other nonlinear measures. His research effort will contribute to the understanding of spatio-temporal complexity in nonlinear systems.

CONTRIBUTION TO EDUCATION

Al is knowledgeable, patient and generous, and is an excellent communicator - qualities of an outstanding teacher and mentor. At Bryn Mawr College, he infused his lectures with humor. One of his stories is the 'curse' of the royal lineage of statistical mechanics. According to Al he belongs to this lineage, which started with Ludwig Boltzmann, one of the founders of statistical mechanics. Max Dresden, Al's doctoral adviser, was a student of George Uhlenbeck, who was student of Paul Ehrenfest, who was a student of Boltzmann. Boltzmann committed suicide and so did Ehrenfest and one student from almost every succeeding generation of students. It seems though that this curse was broken in Al's generation.

Al's contribution to education included research in the further improvement of education. He was the principal investigator of an NSF-funded grant to study Institution-Wide Reform of Undergraduate Education in Science, Mathematics, Engineering and Technology.

Many awards attest to Al's gift for teaching, among them the Carnegie Foundation for the Advancement of Support of Education (CASE) 1996 Pennsylvania Professor of the Year Award.

CONTRIBUTION TO DEVELOPMENT OF SCIENCE IN THE PHILIPPINES

Long before his retirement, Al had started helping scientific research in the Philippines, sharing his expertise in the measures of chaos, which jump-started research on chaos at the National Institute of Physics, University of the Philippines Diliman in the early 1990s. Now in his golden years, he continues his legacy of mentoring and research not only in the US but also in the Philippines.

Through the sponsorship of the Department of Science and Technology's (DOST) Balik Scientist program (BSP), Al went to the Philippines in January 2008. While there, he participated in the workshop at the Research Center for Theoretical Physics in Jagna, Bohol and established contact with the Iligan Institute of Technology (MSU-IIT). Later that year, he returned to the Philippines to hold a 5-day seminar on Nonlinear Dynamics and Time Series at MSU-IIT. In 2009, BSP sponsored another trip during which he conducted two more workshops at MSU-IIT and visited the University of San Carlos (in Cebu) and Silliman University (in Dumaguete).

The visits to IIT paved the way to Al's long term collaboration with the institute. He has supervised, together with a number of IIT faculty members, five masteral students and one doctoral student, three of whom have already graduated. The results of these students' research have been presented in various physics conferences and meetings in the Philippines. One of the studies done in collaboration with an MSU-IIT faculty member resulted in a paper which will soon be published in an international physiology journal.

Al is always seeking opportunities to help promote the development of science in the Philippines. In 2011, he will return to the Philippines for a week-long workshop at IIT. He will also run a similar one at the University of San Carlos (USC) where the physics department has an on-going collaboration with the Space Environment Research Center (SERC) of Kyushu University (Japan) on the Magnetic Data Acquisition System (MAGDAS) project. The project is a globally dense network of magnetometers to monitor the geomagnetic field in real-time at different locations on the surface of the earth. One of the four stations in the Philippines is on the USC campus. Opportunities for research in nonlinear dynamics using this system abound. Al will be there to encourage students' involvement in the analysis of the MAGDAS data.

Al is enjoying his retirement with his wife, Connie, and daughters, Maia and Sarah, and their families. Yet, it seems that he is just starting on a new path. It is a path that many idealistic graduates of the University of the Philippines dream about, which is to return one day to contribute to the improvement of science in the Philippines. Al is surely living this dream. **PSL**

REFERENCES:

Albano AM, Muench J, Schwartz C, Mees AI, Rapp PE. Singular –value decomposition and the Grassberger-Procaccia algorithm. Phys Rev A 1988; 38:3017-3026

Albano AM, BrodFuehrer PD, Cellucci CJ, Tigno XT, Rapp PE. Time Series or the Quest for the quantitative measures of time dependent behavior. Phil Sci Letts 2008; 1:19-31.