# Dimitri Mihalas

1939–2013

BIOGRAPHICAL *Memoirs*

*A Biographical Memoir by*
*Baolian Cheng*

NATIONAL ACADEMY OF SCIENCES

# DIMITRI MANUEL **MIHALAS**

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Dimitri Mihalas

*By Baolian Cheng*

Dimitri Mihalas made outstanding theoretical and observational contributions to the field of astrophysics throughout his professional life. In a long run of exceptional work he developed new and far-reaching methodologies, many of which overturned erroneous assumptions and imposed vastly greater accuracy on astrophysical calculations and conclusions. Beyond his scientific achievements, he was a deeply spiritual man known for his humility, compassion, and profound concern for the well being of others, a man who helped many by openly sharing his hard-won insights in overcoming his struggles with depression and bipolar disorder.

A native of Los Angeles, Mihalas earned a bachelor's degree in 1959 from the University of California at Los Angeles at the age of 20, followed by a Ph.D. in physics and astronomy from the California Institute of Technology in 1963. He then moved to Princeton University, first as a Higgins Visiting Fellow and then as an assistant professor. In 1967 he took a position at the University of Chicago's Yerkes Observatory, followed in 1970 by an appointment to the High Altitude Observatory, in Boulder, Colorado.

Dimitri Manuel Mihalas was a pioneer in astrophysics and computational physics and a world leader in the fields of radiation transport, radiation hydrodynamics, and astrophysical quantitative spectroscopy for most of his career. His broad knowledge and immense contributions earned him election to the U.S. National Academy of Sciences in 1981. Dimitri received many distinguished awards, including the 1974 Helen B. Warner Prize from the American Astronomical Society and a 1984 Alexander von Humboldt Foundation U.S. Senior Scientist Award. He wrote or co-wrote seven books and co-edited three others. Three of these works have been used as textbooks for undergraduate and graduate students worldwide and translated into other languages, including Russian. His book *Foundations of Radiation Hydrodynamics* (Oxford University Press, 1984) is considered the bible of the radiation hydrodynamics community, especially at

Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and the Naval Research Laboratory. His *Stellar Atmospheres* (W. H. Freeman, 1970) remains the standard in the field after nearly 45 years in print.

Dimitri was born on March 20, 1939, in Los Angeles, where he grew up. At 20, he received his B.A. from the University of California at Los Angeles (UCLA), with highest honors in three majors: physics, mathematics, and astronomy. He went to graduate school at the California Institute of Technology (Caltech), concentrating in astronomy and physics. Four years later, in 1963, he received his Ph.D. from Caltech.

## Caltech

Dimitri was trained primarily as an observational astronomer. His first research experience, as an undergraduate, was the reduction of photoelectric and photographic measurements of the total luminosities of galaxies in the giant Coma cluster of galaxies, under the direction of Professor G. O. Abell at UCLA. At Caltech he made similar reductions of measurements of light curves of type Ia supernovae under the direction of Dr. H. C. Arp at the Mount Wilson Observatory.

After completing his course work in his second year at Caltech, Dimitri did his dissertation research under the direction of John Beverley Oke, who at that time had developed the first seeing-compensated photoelectric spectrophotometer at the high-dispersion coudé focus of the 100-inch telescope at Mount Wilson. Having acquired high-quality data on the hydrogen, helium I and helium II line strengths and profiles in O-stars (very young, high-mass, hot stars whose relative He/H abundances should reflect the current abundances in the interstellar medium, hence the cosmic abundance of helium in the universe at its current age), Dimitri set out to interpret these data with the best theoretical analysis possible at the time.

In the early 1960s several important developments made possible a huge advance in the state of the art of quantitative spectroscopic analysis of stellar atmospheres (the radiating layers that we observe): (1) IBM had produced computers (specifically the IBM 7090 and 7094) that, though puny by today's standards, represented a *gigantic* increase in automated computational ability; (2) scientists at the Harvard-Smithsonian Observatory had published an effective mathematical algorithm for constructing stellar atmospheric models in radiative equilibrium for non-gray opacities (not previously possible); and (3) Hans Griem and his students and coworkers at the University of Maryland had developed the first accurate quantum-mechanical theories of pressure-broadening of hydrogen and helium lines. Thus it became possible, for the first time, to calculate accurate hydrogen and helium line profiles for a very large grid of non-gray model atmospheres, covering the effective temperature range from 7200 K to 50,000 K and a wide range of surface gravities. These models were computed using the prevailing theoretical picture, which posited that one could make the simplifying approximation of local thermodynamic equilibrium (LTE). As shown by the high number of citations of the paper, this work, though primitive by today's standards, had a large impact on the field.

The theoretically predicted H and He II line strengths agreed qualitatively with the observational data, but comparisons now possible indicated serious systematic errors in the theory. In particular, the H line strengths were systematically too weak, forcing the diagnostic procedure to give too-high estimates of the surface gravity of these stars (compared with gravities deduced from masses and radii), and both the He I and He II line strengths were too small compared with the data, which forced the diagnostic procedure to indicate too large an He/H ratio (compared with nebular data). However, the ratio of He II/He I line strengths gave nearly the correct atmospheric effective temperature. The resolution of these discrepancies would require another decade of work.

## Princeton and JILA

After completing his Ph.D., Dimitri accepted a position at Princeton University, first as a Higgins Visiting Fellow and then as an assistant professor in the Department of Astrophysical Sciences. There he used his non-gray LTE models for abundance analyses. As he showed later, in work with Dr. Larry H. Auer, these estimates were systematically wrong because of the LTE assumption. Dimitri derived a new method for constructing flux-constant atmospheres including convection, using mixing-length theory, in the full transport regime, as opposed to assuming radiative diffusion. And he made the first line-blanketed spectrum of hot B-stars; this showed that the use of continuum-only models, which neglect line blanketing, causes a serious 10 percent overestimate of a star's effective temperature, thus overpredicting luminosity by about 40 percent. Dimitri also completed a grid of models for H-line-blanketed A-type stars, where the main effect of line blanketing is distortion of the continuum by the confluence of the hydrogen Balmer lines near 3650-Å. Near the end of his stay at Princeton, Dimitri wrote two review articles on basic methodology and future prospects.

After a visit with Dr. R. N. Thomas at the Joint Institute of Laboratory Astrophysics (JILA) at the University of Colorado, Boulder, Dimitri realized that the widely accepted approximation of LTE for stellar atmospheres was inadequate and indefensible. So by 1967 Dimitri began to devote attention to solving the complex, highly nonlinear non-LTE problem, in which one attempts to compute atomic- and ionic-level populations of the atmospheric material completely consistently with the radiation field. This great difficulty arises because, on the one hand, these level populations are *driven* by the *nonlocal* radiation field in the atmosphere, which is the result of absorption, emission, and scattering processes (over possibly very large distances) in the atmosphere, but which, on the other hand, *determine* those absorption, emission, and scattering coefficients, hence the radiation field. This problem had never been solved self-consistently except for the highly idealized case of a two-level atom with a single line, and two continua.

Dimitri first evaluated the observable effects of departures from LTE in continua only. These predictions were validated by observation. The continua are generally much more transparent than spectral lines, which typically are very nearly in radiative detailed balance where the continua are formed. Thus these calculations gave the correct "asymptotic" solution at moderate depth in the atmosphere but did not address the formation of spectrum lines and the direct coupling among resulting atomic and ionic levels.

While at JILA Dimitri joined forces with Larry Auer, whom he first knew as a graduate student at Princeton. This was the start of an extraordinarily fruitful collaboration lasting over 35 years. They first found a method of incorporating the requirement of radiative equilibrium as a *constraint* on the equation of transfer; this method proved to be very effective and quickly convergent. Then, following earlier approaches, they added the Lyman-α line transition by using an analytical source function; this posed a difficult problem, which they solved successfully. In one paper, Dimitri and Auer included only the Balmer-α line (setting Lyman-α in detailed balance); this led to the remarkable, and totally non-classical, result that adding this line produces *heating* of the upper atmosphere by permitting efficient cascades from $n = 3$ (a cooling continuum) to $n = 2$ (a heating continuum). Next they tried to extend these methods to problems with more than one line, but that approach failed utterly.

## University of Chicago

In 1967 Dimitri moved to the Yerkes Observatory of the University of Chicago, and Auer moved to the Astronomy Department at Yale University. They continued their collaboration, however, going back to the beginning and reformulating the whole stellar-atmospheres problem in an unconventional, completely original, and untried way. They linearized the resulting nonlinear equations and iterated them to convergence using a multidimensional Newton-Raphson technique. This radically different approach ensured, physically, that the change in any one variable at any one depth is propagated consistently (to first order) to all variables at all other depths. The new method worked extremely well and was a genuine breakthrough in the field; it revolutionized all further work on computing model stellar atmospheres and remains crucial to all modern codes.

Dimitri and Auer applied their new method to multiline models for O-stars and found, for the first time, precise agreement between the computed strengths of the hydrogen lines in spectra at effective temperatures with those given by observational methods, surface gravities consistent with the stars' observed masses and radii, and a helium abundance in agreement with measurements from emission nebulae. In addition, they showed that the Brackett-$\alpha$ line of hydrogen in O-stars should be in emission, also confirmed by observation. These calculations were made with crude angular quadrature (the Eddington, or $P_1$, approximation) to economize the computation time. But in 1970 Dimitri learned about B. E. Freeman's idea of "variable Eddington factors" at a nuclear weapons conference held at Systems, Science, and Software Corporation in San Diego. Immediately incorporating the variable factors into their code, he and Auer applied it to the stellar atmospheres problem, but with the difference that they computed the Eddington factors directly and *consistently* with the model, rather than using schematic geometric models to estimate them, as done by the weapons community.

## At the High Altitude Observatory

In 1970 Dimitri moved from the University of Chicago to the High Altitude Observatory, a division of the National Center for Atmospheric Research, in Boulder. There he had access to superior computational resources (a CDC 7600) and was able to construct an extensive, and widely cited, grid of non-LTE models for hot stars. He used these to evaluate the effects of departures from LTE on both line and continuum indices. He and Auer used them to compute multilevel-atom line profiles for hydrogen and helium II. This work has been frequently cited over the years both for the goodness of fit to observations and as a gold standard for subsequent calculations based on more approximate methods of solving the transfer equation.

Dimitri used the same series of models to evaluate the effects of departures from LTE on several well-observed light-ion spectra in O- and B-stars: computations for magnesium II showed that the discrepancy between stellar and nebular values of the Mg II/H ratio was the result of the breakdown of the "classical" assumption of LTE; the N III emission lines in O((f)) stars (with R. Brucato, P. S. Conti, and D. G. Hummer), which identified the basic physical mechanism producing the emission; and He I and Ne I, both with Auer.

Dimitri working at home (date unknown).

In these papers they showed that for the hottest stars, LTE models lead to order-of-magnitude errors in abundance estimates of light elements, and that the non-LTE analyses gave results in close agreement with nebular analyses. This important result strongly validated the quantitative spectroscopic techniques for both stars and nebulae.

Dimitri and Auer would have continued these calculations for other ions, but the atomic data (transition probabilities and continuum cross-sections) were lacking, as was any way of evaluating the non-LTE line-blanketed flux in the ultraviolet. In the original development of this method Dimitri had insisted that they make *direct* solutions of the linearized equations to strict convergence, so that when they found differences between LTE and non-LTE predictions they would know that these were genuine physical differences, not numerical artifacts. But this made the method too expensive to apply for large numbers of atomic levels, and impossible for line blanketing. Only about 15 years later were reliable *fast* iterative methods found to solve these problems (in the development of which, by the way, Auer played a seminal role).

## Non-LTE Model and Challenges

Dimitri's research then moved in other directions. With Hummer he developed methods for making non-LTE spherical model atmospheres. Then he devised a now-standard method for solving the line-transfer problem in expanding spherical atmospheres in the co-moving-frame, which is the proper frame (both in the sense of "relativistic" and in the sense of "correct") in which to do absorption, thermal emission, and scattering of radiation. This led to a series of studies in which more complex aspects of the problem were elucidated, up to and including multilevel atoms. Further, Dimitri derived the first exact transfer equation for special-relativistic flows in planar and spherical geometry using the exact transformations for the photon four-momentum and distribution function derived by L. H. Thomas in 1930; today this transfer equation is used in studies of the spectra of supernovae. Soon after, Dimitri outlined how angle-dependent partial redistribution can be formulated in the co-moving frame.

Dimitri summarized all of this work in the second edition of his text *Stellar Atmospheres*, which remains the standard in the field; a third edition, entitled *Theory of Stellar Atmospheres: An Introduction to Astrophysical Non-equilibrium Quantitative Spectroscopic Analysis*, took Dimitri the last 20 years of his life to write; he finished it a few months before to his death. Thanks to his work it is possible at present to construct a fully non-LTE model of, say, the solar atmosphere, including non-LTE blanketing of over a million spectrum lines.

While in Boulder Dimitri, with J. Heasley and A. I. Poland, worked on solar prominences—tenuous, highly nonequilibrium 2-D structures in the Sun's atmosphere. Dimitri also worked with R. W. Milkey to show the dominant importance of "partial redistribution" (that is, general angle- and frequency-dependent scattering) effects in the scattering of photons on the Lyman-a profile in the solar spectrum, obtaining good agreement with the observed wings of the profile for the first time. In subsequent collaborative work with Milkey and R. A. Shine, he evaluated partial redistribution effects on the Ca II lines in the Sun and solar-type stars, and with Hummer, P. B. Kunasz, and Shine on partial redistribution effects in resonance lines in moving media. With Barbara W. Mihalas and Auer, Dimitri developed a code to evaluate 2-D effects in solar structures, which was later extensively used by other astronomers.

Most of the above work was theoretical and computational, but having successfully made the transition from observation to theory, in the period of about 1972 to 1982 Dimitri returned to observational projects. In 1972 he and G. W. Lockwood discovered that the 10124 Å line of He II is in absorption in ordinary O-stars, but in emission in the Of-star ζ Puppis. In 1975 S. A. Frost, Lockwood, and Dimitri were able to establish that the C III $3s^1S$–$3p^1P$ line near 8500 Å is in emission, while the corresponding triplet lines near 4650 Å are in absorption, in direct parallel with the behavior of the *3s–3p* singlet and triplet lines of N III, and hence that these emission features arise from similar mechanisms. During this time Dimitri also participated in large collaborative efforts to measure rotation rates of solar-like stars by following the variations in the Ca II line emission arising from stellar plages, as well as similar efforts using continuum photometry. These data provide direct observational input to solar/stellar dynamo theories for the generation of stellar magnetic fields.

## Radiation hydrodynamics

In 1981 Dimitri was invited by Rodney Wood-Schultz and Robert Weaver to become a consultant for X Division at Los Alamos National Laboratory. Once Dimitri was

Dimitri giving a lecture at a stellar atmosphere modeling conference in Tübingen, Germany, 2002.

cleared and learned how radiation plays the role of a working fluid in some of the Lab's systems, he was so powerfully engaged intellectually that he dropped all his work on the diagnostics and kinematics of nonequilibrium stellar atmospheres and entered the field of radiation hydrodynamics—fluid flow in which radiation dominates the energy content and/or transport in the radiating fluid. This was to be the most stimulating and educational change in all his scientific work, and he continued consulting with X Division until 1998, when he retired from the University of Illinois (see below) at Urbana-Champaign, and came to Los Alamos full-time. During that time he gave numerous lectures and workshops about radiation hydrodynamics to X Division technical staff members, which proved to be a joint learning experience; in 1991 he was given a Certificate of Appreciation by Paul C. White for "outstanding service to the Applied Theoretical Division" for these lectures. Initially, Dimitri worked with Weaver on time-dependent transport with automatic flux-limiting, and with R. I. Klein on the inclusion of O(v/c) terms in the laboratory-frame transport equation. Later he showed that in the diffusion limit, effects of radiative viscosity can be at most $O(v^2/c^2)$ and in the transport limit must be computed directly from the transfer equation. With Barbara he made a fundamental study of full time-dependent propagation of acoustic waves in a radiating fluid. By 1984 Dimitri and Barbara wrote the monograph *Foundations of Radiation Hydrodynamics*, which has become the bible of the radiation hydrodynamics community; it was scanned by X Division and made available to Los Alamos scientists on the laboratory's internal web. In 1999, it was reprinted in inexpensive paper-bound form by Dover Publications, Inc., at the urging of many scientists from Los Alamos, Lawrence Livermore, and the academic community. This book has been openly cited a goodly number of times, but the true citation count is much higher, as the book has been heavily referred to in classified literature.

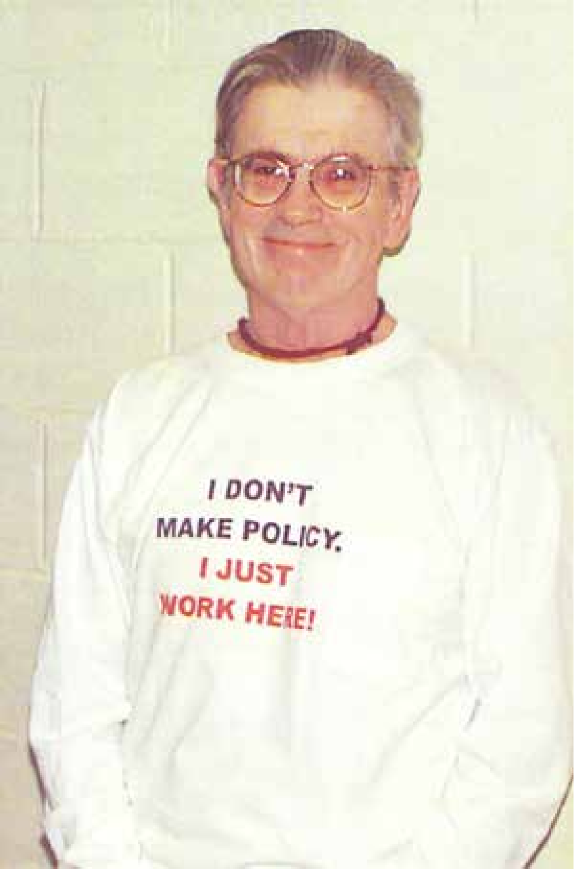
In 1984 Dimitri started a collaboration with K.-H. Winkler and M. L. Norman to learn how to use implicit-adaptive-grid methods to solve difficult 1-D radiation-hydrodynamics problems that have multiple scale lengths ranging over many orders of magnitude. Dimitri derived the 3-D "adaptive-grid transport theorem" as rigorously as the well-known Reynolds transport theorem, which replaced the heuristic methods of Winkler and Norman and allowed *any* conservation law to be expressed in adaptive coordinates, Because this is a *kinematic* transformation in 3-space instead of a *dynamical* one in 4-space, it even carries over to general relativity (C. W. Evans, private communication). Dimitri then wrote the radiation transport equation, its frequency-dependent angular moments, and its angle-frequency-integrated moments on an adaptive grid. Quickly Dimitri and his colleagues presented the idea of "asymmetric time-filtering" discovered by Winkler and Mihalas, which plays an essential role in preventing grid runaways during drastic, but only temporary, changes in grid morphology.

## University of Illinois at Urbana-Champaign

In the period 1987-1994 Dimitri worked with L. Anderson, W. Däppen, D. G. Hummer, and Barbara on the development and application of a modern analytical free-energy minimization code for stellar envelopes, in support of the major British-American Opacity Project (OP) led by Professor M. J. Seaton. The cross-sections were calculated by several groups in London and Belfast using R-matrix close-coupling techniques. The equation of state was used to calculate Rosseland and Planck mean opacities for a variety of stellar and pure-element mixes. What emerged was that the OP gave results in excellent agreement (typically less than ±10 percent) with Lawrence Livermore's completely independent OPAL computations, so that for the first time ever, they had reliable knowledge of the opacities inside stars. The modern results were in serious disagreement with previous Los Alamos (Cox) opacities for important ranges of temperature and density; for example, the discrepancies were up to a factor of 30 for pure iron and up to a factor of 3 for an astrophysical mix composed predominantly of hydrogen and helium! It was shown that these discrepancies resulted from an inadequate inclusion of spectral lines in the Cox work.

The new OP and OPAL data have had significant effects on stellar-evolution computations and have resolved many previously outstanding and troubling problems, especially with the interpretation of Cepheid variable-star pulsations. Since the 1940s astrophysicists have known that the spectral type and hence effective temperature of Cepheids is very nearly the same at maximum for stars having pulsation periods differing by a factor of 10 (whereas their spectral types at minimum are markedly different). In 1993 Dimitri realized, and N. Simon, S. Kanbur and Mihalas verified by calculation, that this fact implies that one is observing the "naked hydrogen-ionization front" emerging through the atmosphere when it arrives at optical depth unity, which is when maximum light would occur. Kanbur has further elaborated this idea successfully for RR-Lyrae variables.

In 1992 Dimitri worked with J. Stone to show that the severe oscillations, or severe diffusion, typically found in numerical simulations of the propagation of a pure radiation front in a vacuum could be eliminated by using upwind monotonic interpolation methods, resulting in both excellent implicit and explicit numerical schemes. They developed more accurate numerical methods for time-dependent radiation transport. They also collaborated on incorporating 2-D radiative transfer into the radiation magneto-hydrodynamics code ZEUS developed at the Laboratory for Computational Astrophysics (LCA) at Illinois.



Dimitri at Los Alamos National Laboratory in 2003.

## TITAN

In the period 1994-1997 Dimitri developed TITAN, a 1-D implicit-adaptive-grid code similar in philosophy to a Winkler-Norman code but completely independently coded and using the Dorfi-Drury grid equation (which has a simple and satisfying geometric interpretation) instead of Winkler's methods. Dimitri and his postdoc M. Gehmeyr demonstrated the capabilities of the code, documented it fully for LCA, and made it publicly available on the web. They used TITAN in collaboration with me at Los Alamos not only to compute the best-ever numerical solution of the infamous Noh stagnating shock problem in planar, cylindrical, and spherical geometry but also to extend the numerical solution to multiple reflections, give analytical solutions for the planar, cylindrical, and spherical cases, and show that the numerical solutions agreed with the analytical solutions for large numbers of shock reflections.

In 1999 Dimitri worked with Sincell and Gehmeyr on the famous Zel'dovich and Heaslet-Baldwin supercritical shock problem. Zel'dovich had predicted analytically the collapse of the post-(viscous) shock radiative-cooling ramp into an optically thin temperature spike; Heaslet and Baldwin were able to construct such solutions by using a numerical method in the upstream and downstream flows and joining them to an analytical solution for the temperature spike. TITAN, having a very large range of scales, was able to solve this problem purely numerically for the first time.

In 1999 Dimitri and Auer wrote, "An X-6 Radiation Hydrodynamics Primer" designed especially for Los Alamos use; well over a hundred copies of this report have been requested and supplied. Two years later they published an incisive discussion of laboratory-frame radiation hydrodynamics, which differs in many important ways from the co-moving-frame formulation, differences not generally understood and appreciated by Los Alamos code-developers. In this work Dimitri derived exact relativistic laboratory-frame expressions for the energy and momentum exchange between material and radiation for the case in which one considers use of mean opacities (for example, Rosseland and Planck means) to be acceptable in the co-moving frame. Dimitri further pointed out that the "opacity" in the momentum-exchange equation is not a scalar (except in a perfectly isotropic radiation field), but because of *optical geometry* in the flow (that is, independent of the state of motion of the material), it is, in general, a 3´3 diagonal matrix. Up to the present time this important point has been ignored completely in all continuum (as opposed to Monte Carlo) treatments of radiation-material momentum exchange in flows of Lab interest. In addition, given that all laboratory (as opposed to astrophysical) flows have small values of v/c (less than ~0.01), Dimitri and Auer sketched practical methods to account for velocity effects in the material-radiation interaction terms.

Dimitri's colleagues and graduate students held him in high esteem and expressed their admiration for him at an *International Conference in Honor of Dimitri Mihalas for his Lifetime Scientific Contributions on the Occasion of his 70th Birthday,* held in Boulder in late March 2009. A symposium was published following the conference. Dimitri gave generously of himself as an adviser, role model, confidant, and friend. To him, everyone was an individual, with his or her own strengths and weaknesses; he would encourage and enthusiastically praise each person. He is cherished by the many students and colleagues whose lives and careers he touched.

## Personal Faith

While Dimitri's scientific contributions are well known to the astronomical community, his religious beliefs and complex inner life are perhaps less so. Spirituality was very important to Dimitri. He had been a devout Quaker since his first Quaker meeting in Boulder, and he frequently attended such gatherings. Dimitri felt a deep affinity for the central tenet of the Quaker faith, the concept of Inner Light, whereby God's own spirit and divine energy are implanted in every human soul. Dimitri explained that the concept of Inner Light is twofold: First, the Inner Light discerns between good and evil, revealing the presence of both in human beings, and through its guidance, offers the alternative of choice. Second, the Inner Light opens the unity of all human beings to our individual consciousness. Dimitri believed that the potential for good, as well as evil, is latent in everyone.

A similar philosophy in Buddhism drew Dimitri's interest to that faith in his later years. He collected a few figures of Kwan Yin, a goddess of mercy and a bodhisattva associated with compassion as venerated by Mahayana Buddhists. Dimitri asked me to teach my three sons the real meaning of Kwan Yin, which he shared through the story of bodhisattva Avalokiteshvara, the eleven-headed, thousand-armed Kwan Yin that Dimitri had bought from Southeast Asia. He said that Kwan Yin had vowed not to rest until she had freed all sentient beings from samsara, or reincarnation. Dimitri felt that the most valuable lesson he had learned from Buddhism was that one's happiness is a state of mind and that serenity has to come from the inside, not the outside.

Dimitri rarely celebrated Christmas or the New Year. But he enjoyed talking about the rebirth of the Sun and especially the vernal equinox in Greek mythology. He said that his name "Dimitri" can be construed in Greek to be Demetrious, son of the earth goddess Demeter.

## Struggles with Depression

Dimitri had a lonely childhood. Being in boarding school from age 5 through 11th grade was an experience that left many psychological wounds, which later intensified. He was diagnosed with depression and bipolar disorder in his 40s, conditions that he felt were rooted in his childhood experiences. He suffered his most severe depression in 1985, after

Dimitri at home in Santa Fe in 2011.

he had moved from Boulder to Champaign-Urbana. The sudden uprooting to the Midwest, a new environment with dreary winters that Dimitri found strange and alien, left him feeling lost and without friends or foundation. In Dimitri's own words, he "was nuked." He sank into darkness. During this difficult period Dimitri learned a great deal about the psychological issues he was experiencing and about bipolar disorder in particular. The depression lasted for a few years, but slowly he found ways to cope and move forward, becoming stronger and better balanced. His religious faith played an important role: he would later explain that when in the deepest darkness, one could best see light and look in the right direction. He said that "in Quakerism we talk about God's Light and Inner Light, the part of God's Light that is reflected in us at all times, but we have to follow this Inner Light." Dimitri wrote about his spirituality and his struggles in his 1996 book *Depression and Spiritual Growth*.

## Helping others

Looking back, Dimitri often said that he had been dead four times. He nearly died twice during the worst of his depression and twice more during a serious 1997 car accident and a coma that followed. Yet Dimitri came to view his personal tribulations as God-given gifts, from which he gained a deeper understanding of life. He used these gifts, and his own talents and openness, to help others in similar situations through his writings, including his essays "A Primer on Depression and Bipolar Disorder" and "Surviving Depression and Bipolar Disorder" and seven published poetry collections—*Trilogy in a Minor Key, Cantata for Six Lives and Continuo, If I Should Die Before I Wake, Dream*

*Shadows, Life Matters, The World is My Witness, A Distant Summons, and Coming Back from the Dead.* Beautiful but painful, Dimitri's poetry revealed himself completely and expressed his thoughts and feelings about the deepest issues of life. He saw his poetry as a gift, something that could not be written at will, but that came from his heart, spontaneously, at the right time and place and related to specific things in his life. The thoughts and insights captured in Dimitri's nontechnical writing have had a profound and positive influence on many people throughout the world.

Dimitri passed away in his sleep at home in Santa Fe, New Mexico, on November 21, 2013, at the age of 74, with his wife, Anke, at his side. At his request, his body was donated to the University of New Mexico Medical School and his library to the New Mexico Institute of Mining and Technology.

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