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Research accomplishments: I think of myself as a theoretical physicist with broad interests. My Princeton senior thesis under Gerald E. Brown's supervision was the first modern theory of **nuclear fission** (Primack, PRL 1966). Although it overturned the liquid drop model of Niels Bohr and John Wheeler (1939), Wheeler gave it highest marks and I graduated as the valedictorian of my class. As an undergraduate I also published papers on plasma fluid dynamics, based on research as a summer employee at Jet Propulsion Lab.

I worked on **theoretical particle physics** as Sid Drell's grad student at the Stanford Linear Accelerator Center (SLAC) 1966-70, as a Junior Fellow of the Harvard Society of Fellows 1970-73, and in my first decade at UCSC (1973-1983). Drell suggested that I figure out what was wrong with the apparent failure of the Drell-Hearn sum rule applied to nuclei, so Stan Brodsky I wrote fundamental papers (1968-69) on how to treat the **electromagnetic interactions of composite systems** such as nuclei. Tom Appelquist and I studied form factors in field theory (1970-72). Appelquist, Helen Quinn, and I wrote some of the first papers on the **SU(2)xU(1) electroweak theory** (1972-73). With Ben Lee and Sam Trieman I did the first calculation of the mass of the charmed quark (1973), and Abraham Pais and I (1973) showed that **CP violation** arises in the cross term between first and second order perturbation theory. Sam Berman and I (1974) showed that **polarized electron scattering** allows a high-precision test of SU(2)xU(1), which resulted in the SLAC experiment whose success helped justify the Nobel Prize for Glashow, Salam, and Weinberg. My first grad student Sander Bais and I did the first precise calculation of the mass of the 't Hooft- Polyakov monopole (1976). Richard Brandt and I showed (1978) how the spin-statistics connection arises for particles with both electric and magnetic charge (dyons). My grad student Jean-Luc Cambier, my postdoc Marc Sher, and I did the first full **finite temperature field theory calculation of neutron decay** (1982), a process relevant to Big Bang Nucleosynthesis. My subsequent research on modern cosmology has sometimes included relevant particle physics.

I am probably best known for helping to create the modern cosmological standard model, ΛCDM. I was the first to propose that the lightest supersymmetric partner is a natural candidate for the dark matter particle (Pagels & Primack 1982), which led to warm dark matter (Blumenthal, Pagels, & Primack 1982). George Blumenthal and I worked out the cold dark matter (**CDM**) power spectrum and began to study its implications for galaxy formation (Primack & Blumenthal 1983). This led to the successful comparison of the cold dark matter theory of structure formation with the first galaxy redshift survey ("Formation of Galaxies and Large-Scale Structure with Cold Dark Matter," Blumenthal, Faber, Primack, & Rees 1984), a fundamental paper that I led. In it we considered both Ω_m=1.0 and Ω_m=0.2, and concluded that the observations favored the lower value. I wrote up my lectures on CDM cosmology at the 1984 Varenna summer school in a preprint (Primack SLAC-PUB-3387, 1984, 176 pages) that was very widely circulated; it provided the introduction to dark matter cosmology for many astronomers. I finished the BFPR paper and the Varenna lecture notes during my sabbatical in 1984 at SLAC, where all the figures were prepared.

In subsequent years my colleagues and I did various theoretical studies of the dark matter universe, including

- contraction of dark matter galactic halos due to baryonic infall (Blumenthal, Faber, Flores, & Primack 1986)
- how to discover dark matter (Primack, Seckel, & Sadoulet, Annual Reviews of Nuclear & Particle Physics 1988)
- calculations of linear power spectra for many CDM variants (John Holtzman's 1989 dissertation based on Blumenthal's and my 1983 code, and comparison with observations Holtzman & Primack 1993)
- dynamical effects of a cosmological constant, including on the growth rate of structure (Lahav, Lilje, Primack, & Rees 1991)
- cosmological structure formation simulations on CDM variants Cold + Hot Dark Matter (Klypin et al. 1993, Primack et al. 1995) and ΛCDM (Klypin, Primack, & Holtzman 1996) compared with observations
- conflicts between steep central dark matter halo profiles in dark matter simulations vs. observations of dwarf galaxies and galaxy clusters (Flores & Primack 1994, based on Ricardo Flores dissertation research with me)
- improvements in semi-analytic modeling of the galaxy population (Rachel Somerville's thesis paper Somerville & Primack 1999; also Somerville, Primack & Faber 2001 and many subsequent papers including "Galaxy properties from the ultraviolet to the far-infrared: ΛCDM models confront observations" (Somerville et al. 2012) and papers in preparation based on Lauren Porter's dissertation research with Somerville and me
- semi-analytic modeling of damped Lyα systems (Ari Maller's dissertation papers with Prochaska, Somerville, and me 2000-2002)
- dark matter halo concentration evolution and angular momentum distribution (James Bullock's dissertation papers with Avishai Dekel, Anatoly Klypin, and me 2001)
- dark matter halo assembly history and angular momentum evolution (my grad student Risa Wechsler's dissertation papers with Avishai Dekel, Anatoly Klypin, and me 2002)
- halo occupation distribution and predicted evolution of the galaxy two-point correlation function (Kravtsov et al. 2004)
- Gini-M_{20} non-parametric classification of galaxy images (Lotz, Primack, & Madau 2004 and many subsequent papers, including observability timescales for morphological indications of galaxy mergers (Lotz, Jonsson, Cox, and Primack 2008, 2011ab) used for measurement of galaxy merger rates compared with theory (Lotz et al. 2011)
- feedback in simulations of disk galaxy major mergers (2006, based on T. J. Cox's dissertation and subsequent collaboration with me)
- shapes of dark matter halos (Brandon Allgood's dissertation paper with me, 2006)
- the *Sunrise* code for producing images from galaxy simulations including the effects of stellar evolution and dust scattering, absorption, and re-emission of light (Patrik Jonsson's dissertation and postdoc research with me, 2002-2010)
- high-resolution *Bolshoi* cosmological simulations compared with observations (Klypin, Trujillo-Gomez, & Primack 2011, Trujillo-Gomez, Klypin, Primack, Romanowsky 2011, Prada et al. 2012, with analyses by Peter Behroozi, Mike Busha, Risa Wechsler et al. 2012, and 2013-2014 Klypin-Primack *Bolshoi-Planck* simulations now being prepared for publication)

■ high-resolution hydrodynamic cosmological galaxy simulations, including roles of cold streams and violent disk instabilities, compared with HST CANDELS survey (papers with Daniel Ceverino, Avishai Dekel, Sandra Faber, Anatoly Klypin, et al. 2010-)

Another main interest of mine has been **extragalactic background light and gamma-ray attenuation** by $\gamma\gamma \rightarrow e^+e^-$, starting with "Probing the Era of Galaxy Formation via TeV Gamma Ray Absorption by the Near Infrared Extragalactic Background" (MacMinn & Primack 1996, based on Donn MacMinn's senior thesis research with me). Key recent papers include GeV gamma-ray attenuation and the high-redshift UV background (Gilmore et al. 2008), Modeling GRBs (Gilmore, Prada, & Primack 2010), EBL and Gamma-ray Attenuation (Primack et al. 2011), EBL Inferred from AEGIS Galaxy-SED-type Fractions (Dominguez et al. 2011), Semi-analytic Modeling of the EBL and Gamma-ray Attenuation (Gilmore et al. 2012), IACT observations of gamma-ray bursts: prospects for the Cherenkov Telescope Array (Gilmore et al. 2013), "Detection of the Cosmic Gamma-ray Horizon from Multiwavelength Observations of Blazars" (Dominguez et al. 2013), based on dissertation research with me by Rudy Gilmore and Alberto Dominguez and our subsequent collaborations. We have a popular article about all this in the June 2015 *Scientific American,* and Dominguez and I are writing a review of the EBL for *Reports of Progress in Physics*.

Scientific leadership: I led the University of California systemwide High-Performance AstroComputing Center (**UC-HiPACC**), for which I wrote the successful proposal in 2009, and which I have directed from when it began in January 2010 through 2015, with an annual UC budget of $350,000 plus funds raised through grants and gifts. I supervised a part-time staff of four (administrator Sue Grasso, writer Trudy Bell, visualizer Alex Bogert, webmaster Steven Zaslaw), and organized conferences, workshops, a small grants program, outreach activities including a visualization gallery on the HiPACC website, and an **International Summer School on AstroComputing** in which students from around the world attended lectures in the morning and used supercomputer accounts to learn to use relevant codes in hands-on afternoon sessions. The UC-HiPACC summer school topics were galaxy formation at UCSC in 2010, explosive astrophysics at UCB/LBNL in 2011, astro-informatics at UCSD in 2012, star and planet formation at UCSC in 2013, and nuclear astrophysics in 2014 at UCSD (with slides and videos of all lectures online). I also organize the annual **Santa Cruz Galaxy Workshop**. I am co-I of the UCSC astronomical computing center and PI of our new PB AstroData storage and server system. I am also director of the new UCSC 3D Astronomical Visualization Lab.

With my UCSC colleague Piero Madau, I also initiated the **Assembling Galaxies of Resolved Anatomy** (AGORA) project (first paper: Ji-hoon Kim et al. 2014). The goal of AGORA is to improve our understanding of galaxy formation and evolution by running high-resolution galaxy simulations starting from the same zoom-in cosmological initial conditions and as much as possible using the same physics and the same volumetric data analysis and visualization code (yt), and comparing these simulations to each other, to fundamental theory for verification, and to observations for validation. I led a successful National Energy Research Scientific Computing Center (NERSC) Data Intensive Computing Pilot Program proposal to support AGORA, which will provide at

least 100TB of data storage and 5M cpu-hours of NERSC supercomputer time for analysis and visualization of the outputs from the many AGORA simulations starting in January 2014.

I have been continuously supported by NSF and/or NASA grants ever since coming to UCSC in 1973, and I have administered an active research group. I have for many years been a major user of NASA's supercomputers at NASA Ames Research Center and DOE supercomputers at NERSC, and I have received allocations of supercomputer time often totaling more than 10M cpu-hours per year. I have participated as a Co-I in three proposals, all successful, for Major Research Instrumentation grants from NSF to acquire astrophysical computing hardware at UCSC.

I have also helped to start many other institutions related to science and technology. This began with the **Stanford Workshops on Political and Social Issues (SWOPSI)**, which I initiated in my last year as a graduate student at Stanford in fall 1969, along with student body co-president Joyce Kobayashi and my fellow Princeton valedictorian and Sid Drell grad student Bob Jaffe. SWOPSI lasted 20 years and led to many new initiatives at Stanford, including the Center for International Security and Arms Control (which grew out of the 1970 SWOPSI course on Arms Control and Disarmament co-taught by SLAC Director Wolfgang Panofsky). In the SWOPSI course on science and technology in government that I co-organized with Jaffe, Martin Perl, and Frank von Hippel, I led the focus on science and technology policy in Congress, including a questionnaire of Senate and House members in collaboration with then California Senator Alan Cranston and Representative Jeffrey Cohelan. That led in turn to my leadership in 1972-73 in creating the **Congressional Science and Technology Fellowship program**, both in the American Physical Society (APS) and in the American Association for the Advancement of Science (AAAS). I designed the program working with AAAS officers (especially treasurer Bill Golden) and members of Congress and their staffs, recruited the first year Congressional Fellows, and raised the initial funds. AAAS has coordinated the program ever since. It now includes about 50 scientists per year who serve on the staffs of Senators, Representatives, and Congressional Committees. This was the beginning of the AAAS Fellowships program, which is now quite extensive. During the same period, I proposed the name of the **APS Forum on Physics and Society** (FPS) and helped to bring it into existence; I later served as chairman of the FPS (2005). I also led the effort to organize the first **APS studies on public policy issues**, beginning with the study on nuclear reactor safety for which Freeman Dysan and I wrote the proposal and I led the fund raising (1973-74). Frank von Hippel and I wrote *Advice and Dissent: Scientists in the Political Arena* (Basic Books 1974), and we worked with Senator Ted Kennedy in 1976-78 to create the **NSF Science for Citizens Program**. As a charter member of the AAAS Committee on Scientific Freedom and Responsibility (1976-80), I initiated and organized the **AAAS Science and Human Rights** program, which has become a major AAAS activity that has rescued many scientists and non-scientists. In 1987-89 I led the **Federation of American Scientists Space Nuclear Power Arms Control** project, which succeeded in ending the USSR's space nuclear reactor program. As a member 2002-04 of the APS Panel on Public Affairs (POPA), I led an APS study on the negative effects on science of President Bush's 2004 Vision for Space Exploration, and our hard-

hitting report was endorsed by the APS Council. Then-NASA Administrator Sean O'Keefe resigned shortly after our report was released, and the next NASA Administrator Michael Griffin reversed many of O'Keefe's decisions.

Teaching and education, including public education: At UCSC I have taught at every level from introductory undergraduate courses through advanced graduate courses on quantum field theory, group theory, and cosmology. I have also supervised all or part of the research of 45 graduate students and 10 postdocs, many of whom have gone on to distinguished careers. In academic year 2013-14, my UCSC courses are Physics 5D Thermodynamics in Fall 2013, Physics 129 Nuclear and Particle Astrophysics (a new upper division course that I initiated) and Physics 205 Introduction to Research (for beginning grad students) in Winter 2014, and Physics 224 Particle Astrophysics and Cosmology (for grad students in physics and astrophysics) in Spring 2014. In 2013 I also lectured at four schools for advanced graduate students and postdocs: the Jerusalem Winter School on Galaxy Formation in January (where my lectures included the opening and closing talks), the Institute for Cosmology and Philosophy (which I co-organized) and the UC-HiPACC school on Star and Planet Formation at UCSC in July, and the School on AstroParticle and Underground Physics at Asilomar in September. This past year I also gave talks at international conferences and colloquia and seminars at several universities. I have also given many public lectures at universities, including as the Lansdowne Lecturer at the University of Victoria, the J. Robert Oppenheimer Memorial Lecturer at Los Alamos, and the Buhl Lecturer at Carnegie Mellon University.

At UCSC I have developed many **new courses**, including a sequence of freshman honors introductory physics courses and a popular course on Cosmology and Culture that I co-taught in 1996-2009 with my wife, historian and philosopher of science Nancy Ellen Abrams. This course won awards from the John Templeton Foundation and the American Council of Learned Societies, and was the basis for our first book, *The View from the Center of the Universe: Discovering Our Extraordinary Place in the Cosmos* (Penguin/Riverhead 2006), also published in several foreign editions (see http://viewfromthecenter.com/). Nancy and I have given many **public lectures on modern cosmology and its implications** at Berkeley, Cambridge, Columbia, Harvard, Oxford, Peking, Princeton, Stanford, other universities and other venues around the world including the keynote talk at the 2008 Army Science Conference, the Benjamin Dean Lecture at the California Academy of Sciences, and the Frontiers of Astrophysics Lecture at the Hayden Planetarium of the American Museum of Natural History, New York (for a complete list see http://new-universe.org/pastevents.html). At Yale University in October 2009 we gave the Terry Lectures, which became the basis for *The New Universe and the Human Future: How a Shared Cosmology Could Transform the World* (Yale University Press, 2011, with associated website http://new-universe.org; Spanish edition *El nuevo universo y el futuro de la humanidad: Cómo la nueva ciencia del cosmos transformará el mundo* (Barcelona: Antoni Bosch, 2013) http://www.el-nuevo-universo.com/).

Along with the books and lectures just mentioned, I have devoted much additional effort to **public outreach**. I was one of the main advisors to the Smithsonian Air and Space Museum IMAX film Cosmic Voyage (1995) and I co-organized with Owen Gingerich

the AAAS Cosmic Questions conference at the Smithsonian Museum of Natural History (1999). I have provided visualizations and advice for Adler, Hayden, and Morrison planetarium shows about cosmology (2010-2014) and I have explained and visualized the modern theory of the universe in TV documentaries such as National Geographic TV's Inside the Milky Way (2010), where I also led a tour of NASA's supercomputers at NASA Ames Research Center. I have also given keynote talks about the research opportunities and computational challenges of modern cosmology and astrophysics at industrial conferences including the 2012 IEEE Aerospace Conference in Big Sky, Montana, the 2012 Huawei Cloud Congress in Shanghai, and the 2013 Vail Computer Elements Workshop. My recent popular articles include "Universe on Fast Forward," the cover article in the July 2012 *Sky & Telescope*, coauthored with Trudy Bell, and "The Cosmological Supercomputer," *IEEE Spectrum* October 2012. A coauthored article about the CANDELS survey is the cover article in the June 2014 *Sky & Telescope*. An article about measuring all the light in the universe using gamma rays by my former PhD student Alberto Dominguez, me, and Trudy Bell is in the June 2015 issue of *Scientific American*. I am also working on a popular book about computer simulations and big data in science, emphasizing cosmology and astrophysics.