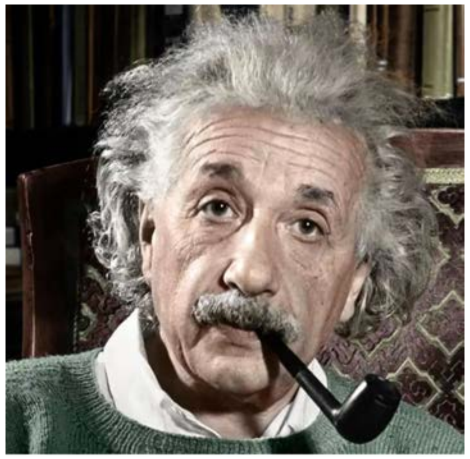
’66 Tiger Talk - November 17, 2021

Joel Primack

Adventures in Science and Politics

“the first good thing I ever heard about uranium”

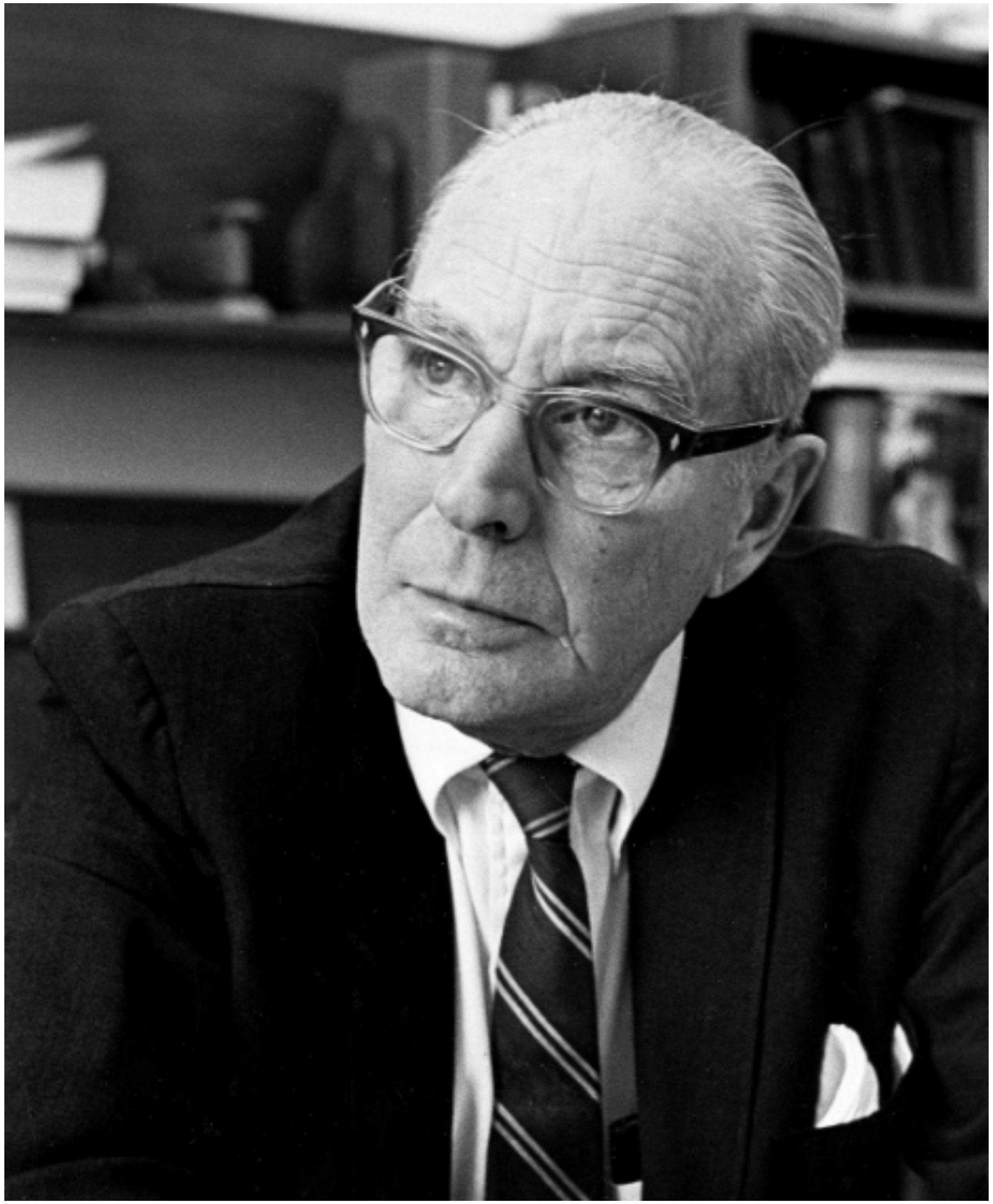
Three scientists who were heroes of mine and helped to inspire me by their examples were **Albert Einstein**, **Andrei Sakharov**, and **Linus Pauling**.



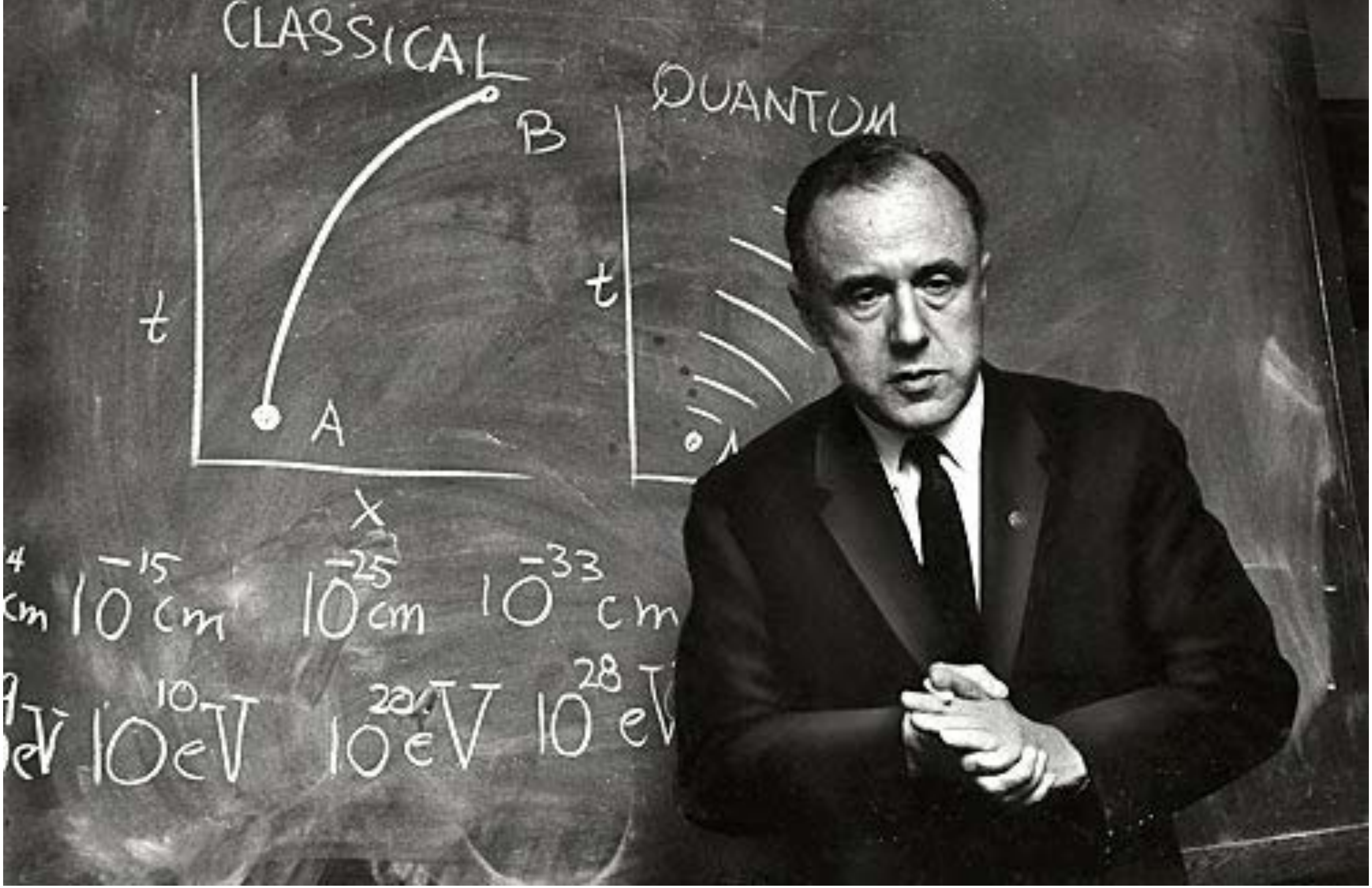
I read Einstein's *Out of My Later Years* when I was about ten years old. Einstein's science, philosophy, and activism have inspired me ever since.

Sakharov's book *Progress, Coexistence, and Intellectual Freedom* (1968) convinced me that the Cold War could be replaced by a more hopeful world. Despite his earlier leadership of the Soviet hydrogen bomb program, Sakharov won the Nobel Peace Prize in 1975 as a "spokesman for the conscience of mankind." I fortunately was able to help Sakharov in 1982 and meet with him in 1988.

Pauling was an early leader in applying quantum mechanics to chemistry, for which he received the Nobel Prize for Chemistry in 1954. He was awarded the Nobel Peace Prize in 1962 for his leadership in ending atmospheric testing of nuclear weapons. He went on to show statistically that smoking causes cancer.



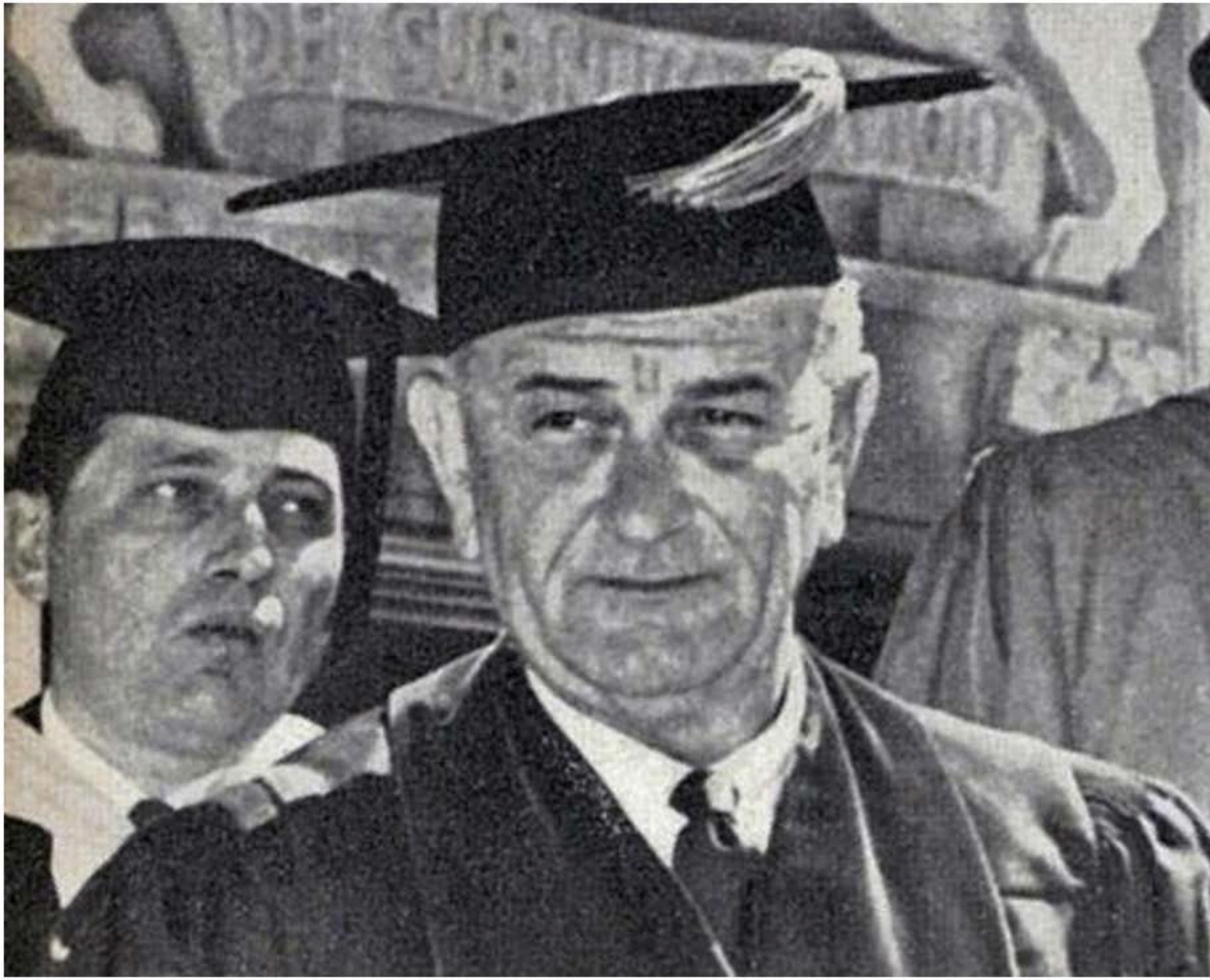
L. Winchester Jones ’22
Caltech Dean of Admission
& Professor of English



John Archibald Wheeler

Princeton Professor of Physics

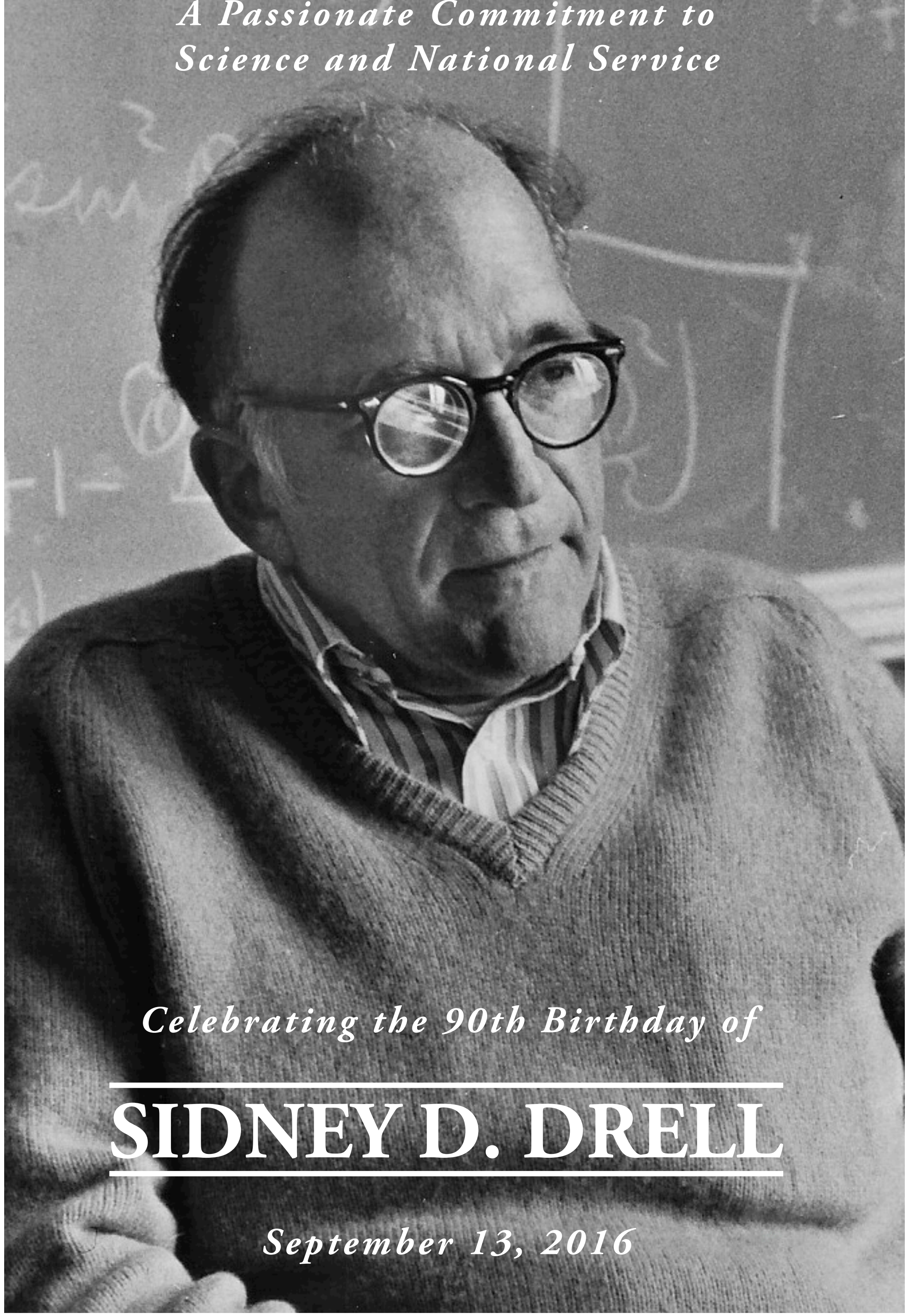
Freshman Physics Course - GR - Senior Thesis on Quantum Theory of Fission - Teller



President Lyndon Johnson at the Wilson School dedication, 1966

PAW, May 31, 1966

Jon Wiener '66



Sid Drell '47
SLAC Deputy Director
my PhD Advisor

with George P. Shultz '42
US Secretary of State,
Treasury, & Labor

1966-70 PhD at Stanford / Stanford Linear Accelerator Center

1967-69 Grad Resident Assistant at Stanford's 1st Co-Ed Dorm

France Córdova credits an informal course I led there for awakening her interest in physics.

1969-70 Stanford Workshops on Political and Social Issues (SWOPSI)

I started SWOPSI with Stanford student body co-president Joyce Kobayashi and **Bob Jaffe, Princeton '68 valedictorian,** who also had **Sid Drell '47** as his PhD advisor. **The goal of each course was to improve the world as well as to educate the participants**. Ten Stanford classes were offered in 1969-70 for credit, taught by grad students as well as Stanford faculty members. **Ned Groth '66** co-led the SWOPSI course on Air Pollution in the Bay Area with Prof. Paul Ehrlich.

SWOPSI was abolished in 1992 when Condoleezza Rice was Stanford Provost.


S.W.O.P.S.I.


SCIENTISTS, ENGINEERS, AND
DECISION MAKING IN WASHINGTON

Leaders: Frank von Hippel (Asst Professor, Physics)
Martin Perl (Professor at SLAC, co-founder of Scientists and Engineers for Social and Political Action)
Joel Primack (graduate student in Physics)
Robert Jaffe (graduate student in Physics)

Decisions concerning about one-third of the national budget — for example, on ABM and other military research, or pollution and the technological destruction of the natural environment — involve complex technological questions. The future of man rests on the outcome of these decisions.

This workshop will seek to understand the role played by scientists and engineers in federal decision making on technological issues. Do outside experts like the Presidents' Science Advisory Committee substantively influence decisions? Are "in-house" advisors free to criticize policy decisions? What are the political, professional and organizational affiliations of advisors? What are the alternatives to the present advisory system?

Most observers agree on the inadequacy of the technical input in technical decisions made by Congress. After surveying Congressmen as to the shortcomings in the scientific advice they receive, we hope to propose a more effective system for bringing scientific and technical advice to Congress. Perhaps we may also be able to find a more successful system for influencing technological decisions by the Executive branch of the government than presently exists.

(1995 Nobel Laureate Martin Perl died in 2014. Bob Jaffe is now at MIT, Joel Primack is at UCSC, Frank von Hippel is at Princeton.)

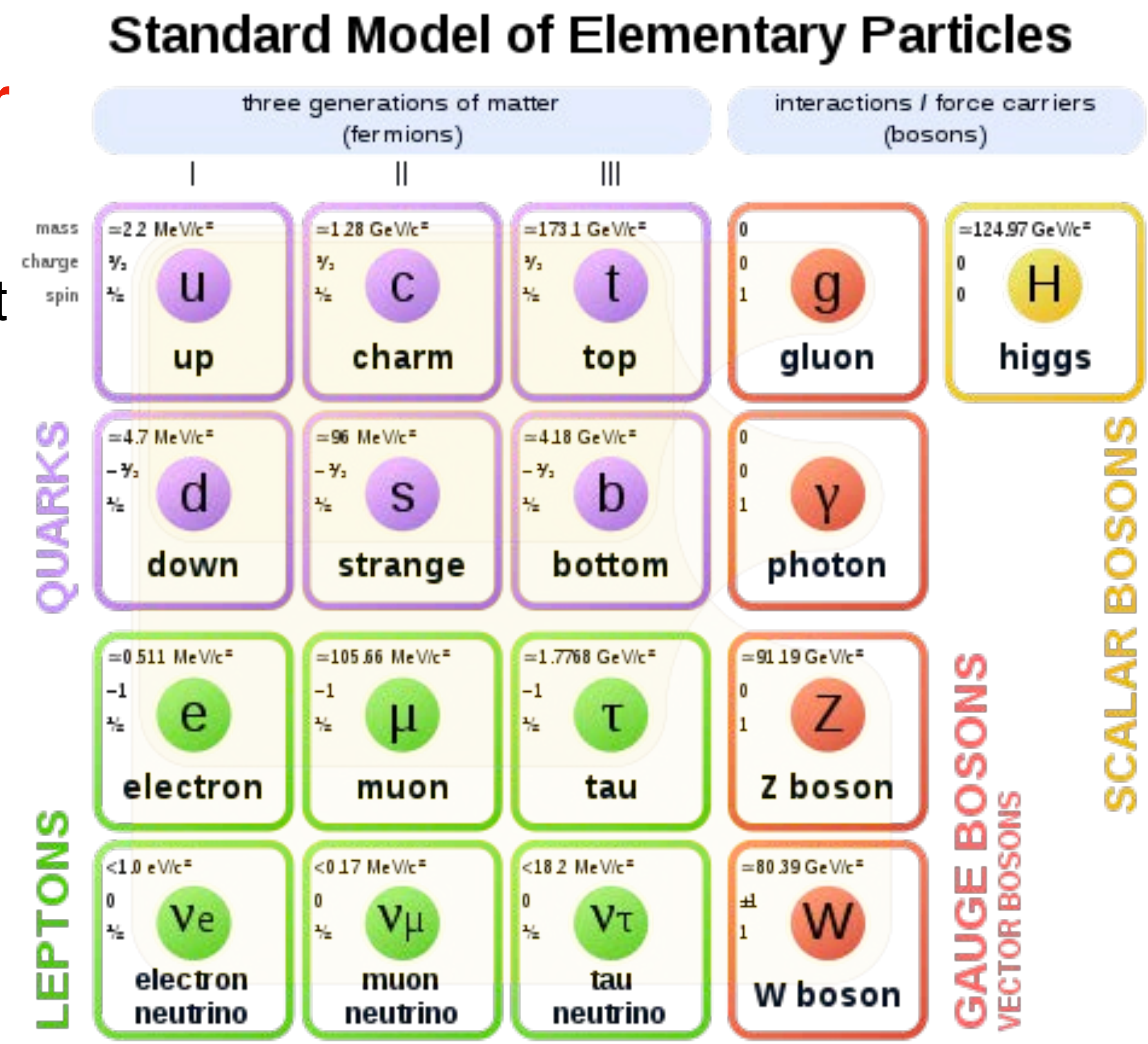
In fall 1969, Bob Jaffe & I, who were then Stanford grad students working on high energy physics, started Stanford Workshops on Political and Social Issues (SWOPSI) with student body president Joyce Kobayashi. SWOPSI continued for about 20 years. In fall 1969, Jaffe and I co-led one of the first SWOPSI workshops with Martin Perl and Frank von Hippel, on the topic of **Scientists, Engineers, and Decision-Making in Washington**. One of the class projects was to do a survey of U.S. senators and representatives, with the help of California Senator Alan Cranston and Representative Jeffrey Cohelan. The idea that was most popular was to create a program for scientists to spend a year working with members of Congress, and this led me to help create the Congressional Science and Technology Fellowship Program of the American Physical Society and AAAS.

One of my arguments for establishing the Congressional Fellowship program in 1973 was that it would **give scientists experience and connections that could empower them to succeed in a wide variety of careers**. The career paths of the roughly 2000 Congressional Fellows have indeed been diverse. **Rush Holt** went on to serve in the State Department and as deputy director of the **Princeton** Plasma Physics Laboratory. From 1999 to 2014 Rush was the **Congressman from the New Jersey district that includes Princeton**, and he then became AAAS CEO. Other Congressional Fellows went on to serve on Congressional staffs or in the Executive Branch, and many others are at universities or laboratories, in industry, on professional society staffs, and at public interest organizations.

AAAS expanded the Congressional Fellowships into the Science and Technology Policy Fellowship program, which in 2020-2021 totaled 226 fellows:

226 AAAS Science and Technology Policy Fellows 2020-2021

When I finished my PhD at Stanford in 1970, **I became a Junior Fellow of the Harvard Society of Fellows**, a wonderful postdoctoral opportunity. The physics papers that I wrote as a Junior Fellow helped to create the "Standard Model of Particle Physics." In 1972, Ben Lee, Sam Treiman, and I used the new theory to successfully predict the mass of the charm quark, which was discovered in 1974.



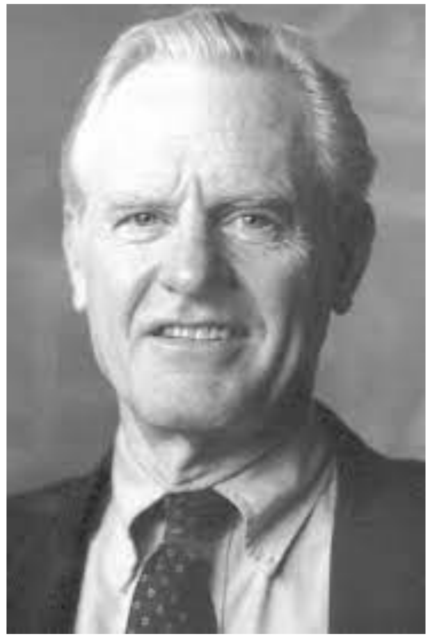
Edward M. Purcell

Harvard Professor of Physics

Nobel Prize 1952

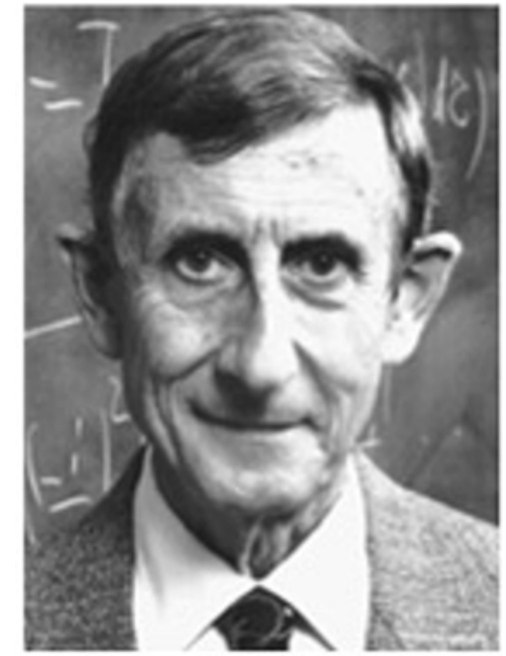
Ed Purcell, the physics Senior Fellow of the Society of Fellows when I was a Junior Fellow, was president of the American Physical Society in 1970. He liked my science and politics ideas, and he got me appointed to many relevant committees of the APS and the AAAS.

1971-72 I worked on reactor safety with **Union of Concerned Scientists** founder Henry Kendall



Henry Kendall
MIT Physics Professor
Nobel Prize 1990

In 1973 I started the **American Physical Society's program of studies on public policy issues**. Freeman Dyson and I drafted the proposal for the first of these studies, on Light Water Reactor Safety.



Freeman Dyson
Institute for Advanced Study

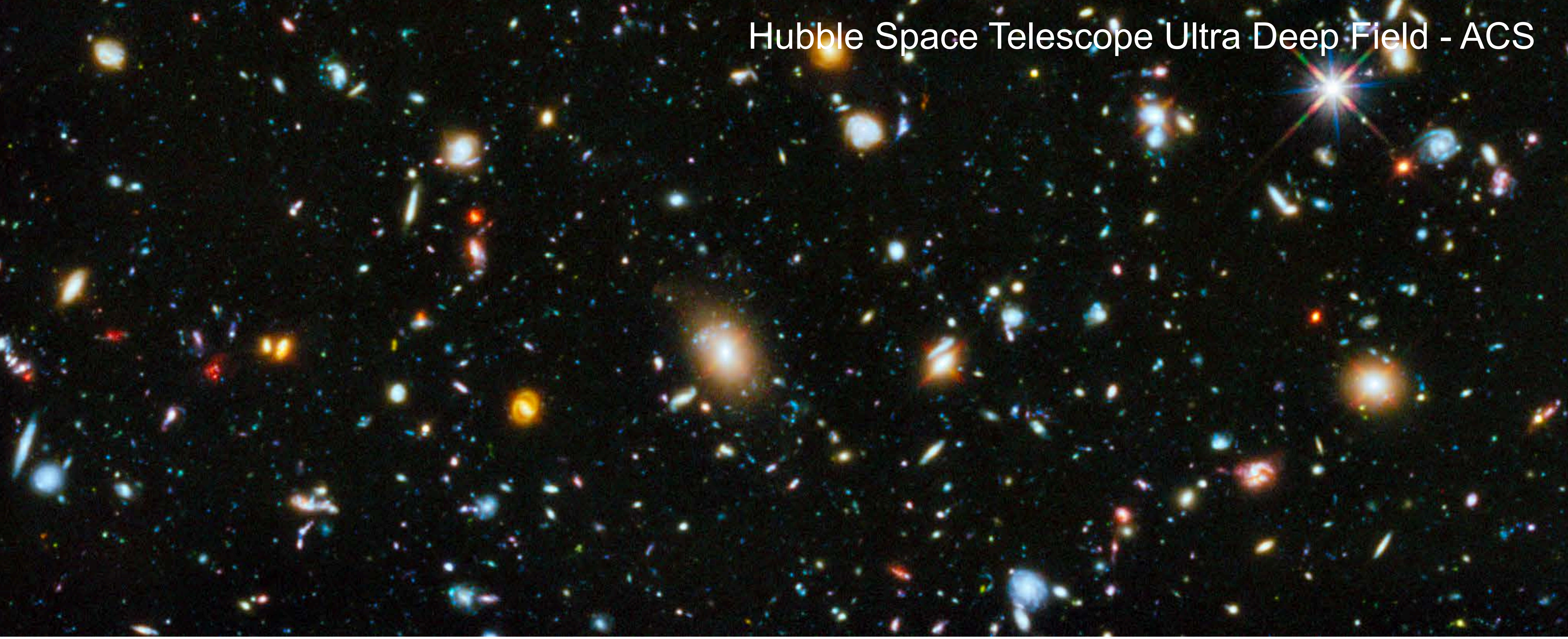
In 1976 I started the **AAAS Program on Science and Human Rights**.

Requirements to create enduring social innovations like SWOPSI, the Congressional Science Fellowship Program, the APS studies, and the AAAS Science and Human Rights program:

1. Must be **"spherically sensible" – it has to make sense from everyone's perspective**. The Fellowship program, for example, benefited the fellows themselves, Congress, their professional societies – as well as their scientific professions and the larger national interest.
2. Recruit excellent people.
3. Initiators like me get out of the way! It is essential that the people who do all the hard work have managerial responsibility and get credit for their successes.

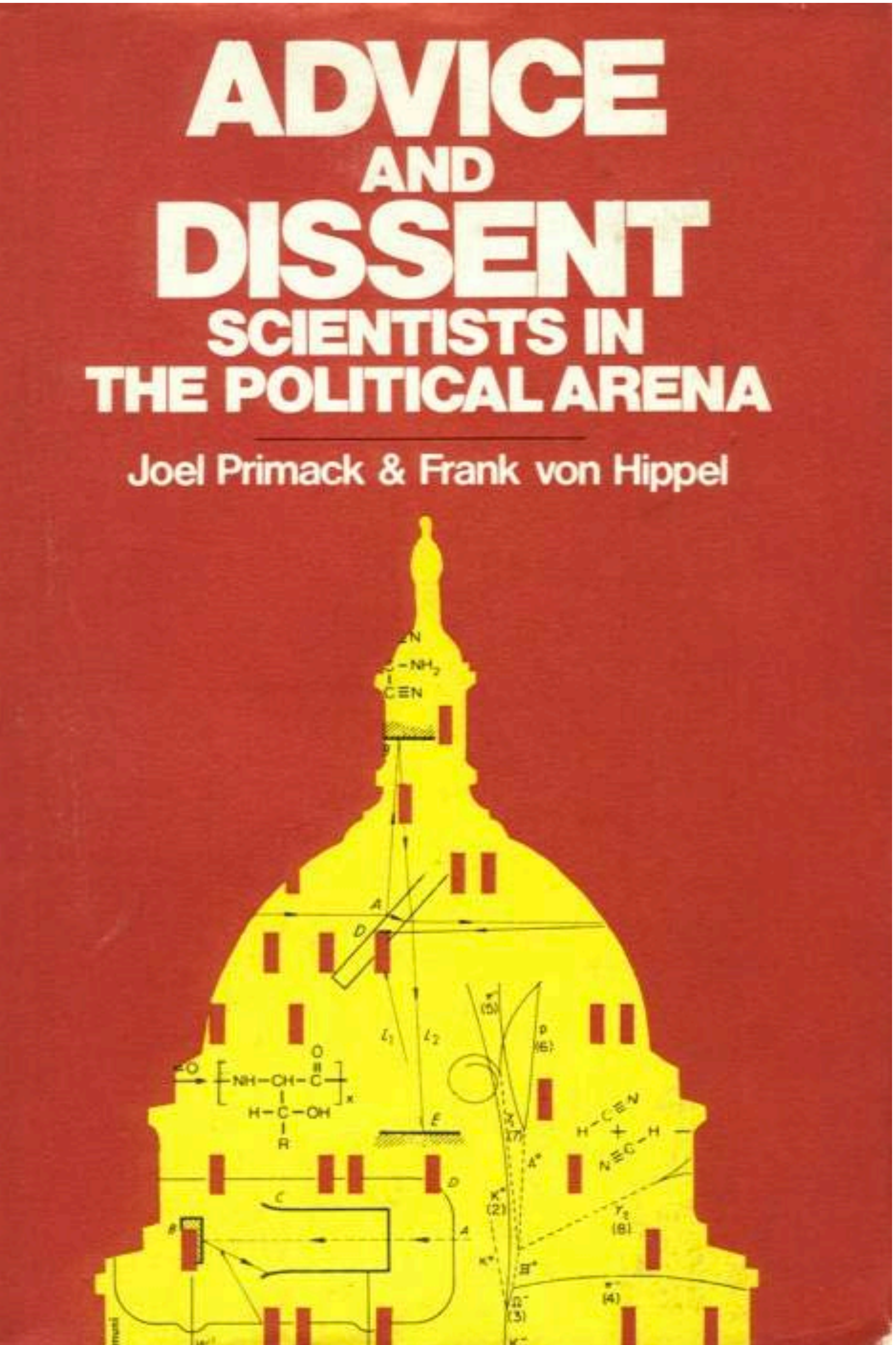
In 1973 when my term at the Society of Fellows ended, I had faculty offers across the country. I had three offers in New York City alone: Columbia, Rockefeller, and NYU. I ignored all of them. I had fallen in love with the San Francisco Bay area, and I wanted to come back. And so, it just came down to Stanford versus Santa Cruz. Sid Drell said, "You'd be crazy to go to Stanford. They're still nuts." And in fact, the faculty at Stanford who were trying to hire me said, "You better not do any of this politics stuff," like the Stanford Workshops on Political and Social Issues that I'd helped to start.

So I went to UC Santa Cruz. It was an incredibly lucky choice because Santa Cruz would increasingly become one of the great centers for astro-physics — the field that I switched to in the late 1970s.



My approach in science has been to **go where the data is**. I was an elementary particle theorist in my graduate research and for the next decade or so. But particle physics became boring by the mid-70s. There are only a few new things we've learned since then in particle physics, and mostly not from accelerators, except for the Higgs, but from neutrinos, which are mostly coming from space. So there was really a lack of new data to lead to new discoveries in particle physics.

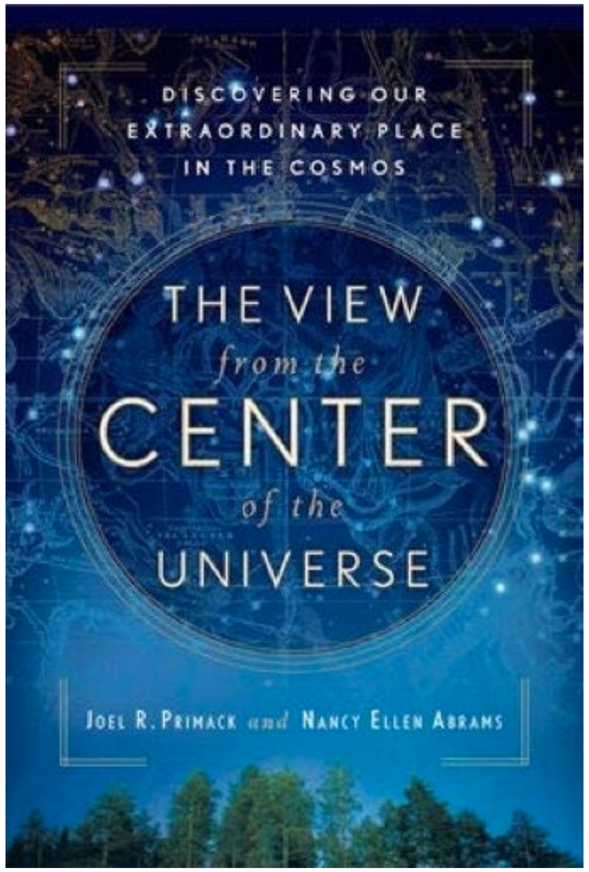
At the same time, **astrophysics became extremely exciting**, with fundamental questions, the opportunity to propose fundamental answers, and huge amounts of data. The quantity and quality of astrophysics data that we're going to be getting in the next half-decade is going to dwarf anything we've ever seen before.

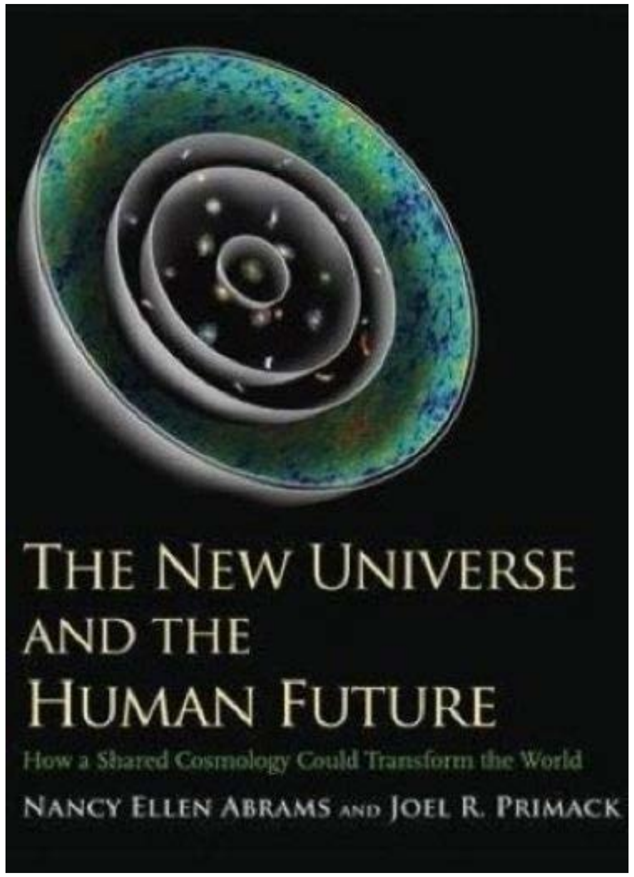


This 1974 book's goal was to improve decisions on technology by improving both **advice** (from scientists to government) and **dissent** (political advocacy by scientists and their organizations). We presented case studies of technological issues – ABM, SST, cyclamates, persistent pesticides, chemical and biological warfare, nuclear reactor safety. We concluded that insider scientific advisors can tell government officials how to do better what they have already decided to do, but that turning government decisions around usually requires outsider activism.

Frank von Hippel and I worked with Senator Ted Kennedy to create the **NSF Science for Citizens** program, which was signed into law in 1977. The basic premise of the "**public interest science**" movement was that the solution was providing **improved knowledge** (for example, through studies) and **expertise**. Several thousand scientists have now become what former President Science Advisor Neal Lane calls "civic scientists."

This also led to my meeting Nancy Ellen Abrams, to our 1997 marriage, and our very happy collaboration ever since!





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Giant voids in the Universe

Ya. B. Zeldovich*, J. Einasto†‡ & S. F. Shandarin*

1982 Nature
300, 407

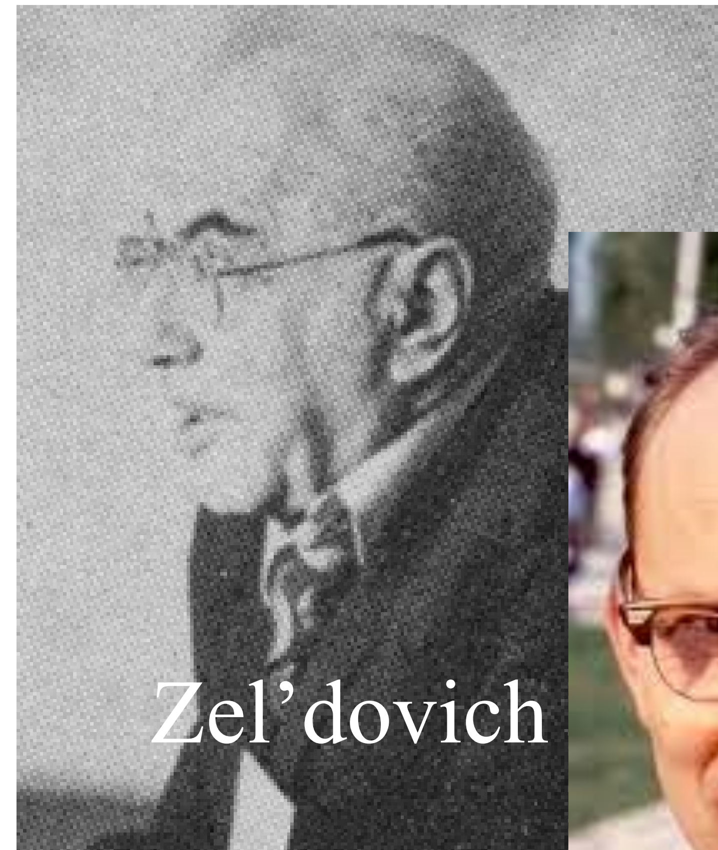
Neutrino dominated Universe

Perhaps the weakest point in the adiabatic scenario is its need for too large an amplitude of density perturbations at the decoupling era: $\delta\rho/\rho \approx 10^{-3}$ if $\Omega = 1$ and $\delta\rho/\rho \approx 10^{-1}$ if $\Omega = 0.02$ (ref. 40). As noted already by Silk[23], density fluctuations at the epoch of decoupling correspond to similar angular fluctuations of the temperature of the microwave background. $\delta T/T \sim 1/3\delta\rho/\rho$. On the other hand, observations give an upper limit of temperature fluctuations of the order 10^{-4} (refs 22, 23).

This controversy would be solved if the Universe were neutrino dominated with the neutrino mass $m \approx 10$ eV. Neutrino gas does not interact with radiation, thus perturbations in the neutrino gas could develop much earlier than in the baryon dominated Universe and could have the necessary amplitude. Baryon gas is bound to radiation and has smaller density fluctuations, after decoupling it simply flows to gravitational wells formed in the neutrino gas.

Thus in the neutrino dominated Universe one has low baryon density $\Omega_b \approx 0.01$–0.1 while the total density is close to the closure once $\Omega_t \approx \Omega_\nu \approx 1$.

The formation of the structure in a neutrino dominated Universe is, essentially, an adiabatic scenario[44–51]. The initial ratio of baryons to neutrinos is the same everywhere (the entropy is constant), small-scale fluctuations are damped, the characteristic mass of objects to form first is $10^{15} M_\odot$ as in the conventional adiabatic scenario.



Galaxy formation by dissipationless particles heavier than neutrinos

1982 Nature 299, 37

George R. Blumenthal*, Heinz Pagels† & Joel R. Primack‡

* Lick Observatory, Board of Studies in Astronomy and Astrophysics, ‡ Board of Studies in Physics, University of California, Santa Cruz, California 95064, USA
† The Rockefeller University, New York, New York 10021, USA

In a baryon dominated universe, there is no scale length corresponding to the masses of galaxies. If neutrinos with mass <50 eV dominate the present mass density of the universe, then their Jeans mass $M_{J\nu} \sim 10^{16} M_{\odot}$, which resembles supercluster rather than galactic masses. Neutral particles that interact much more weakly than neutrinos would decouple much earlier, have a smaller number density today, and consequently could have a mass >50 eV without exceeding the observational mass density limit. A candidate particle is the gravitino, the spin 3/2 supersymmetric partner of the graviton, which has been shown[1] to have a mass ≤1 keV if stable[2]. The Jeans mass for a 1-keV noninteracting particle is $\sim 10^{12} M_{\odot}$, about the mass of a typical spiral galaxy including the nonluminous halo. We suggest here that the gravitino dominated universe can produce galaxies by gravitational instability while avoiding several observational difficulties associated with the neutrino dominated universe.

George Blumenthal

Heinz Pagels ’60
PhD with Sid Drell

1982 ApJ 263, L1

LARGE-SCALE BACKGROUND TEMPERATURE AND MASS FLUCTUATIONS DUE TO SCALE-INVARIANT PRIMEVAL PERTURBATIONS

P. J. E. PEEBLES
Joseph Henry Laboratories, Physics Department, Princeton University

Nobel Prize 2020

Received 1982 July 2; accepted 1982 August 13

ABSTRACT

The large-scale anisotropy of the microwave background and the large-scale fluctuations in the mass distribution are discussed under the assumptions that the universe is dominated by very massive, weakly interacting particles and that the primeval density fluctuations were adiabatic with the scale-invariant spectrum $P \propto$ wavenumber. This model yields a characteristic mass comparable to that of a large galaxy independent of the particle mass, m_x, if $m_x \gtrsim 1$ keV. The expected background temperature fluctuations are well below present observational limits.

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Formation of galaxies and large-scale structure with cold dark matter

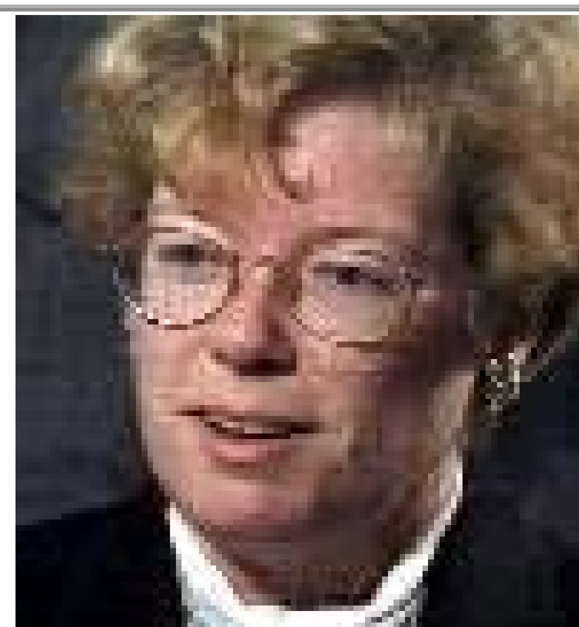
George R. Blumenthal* & S. M. Faber*

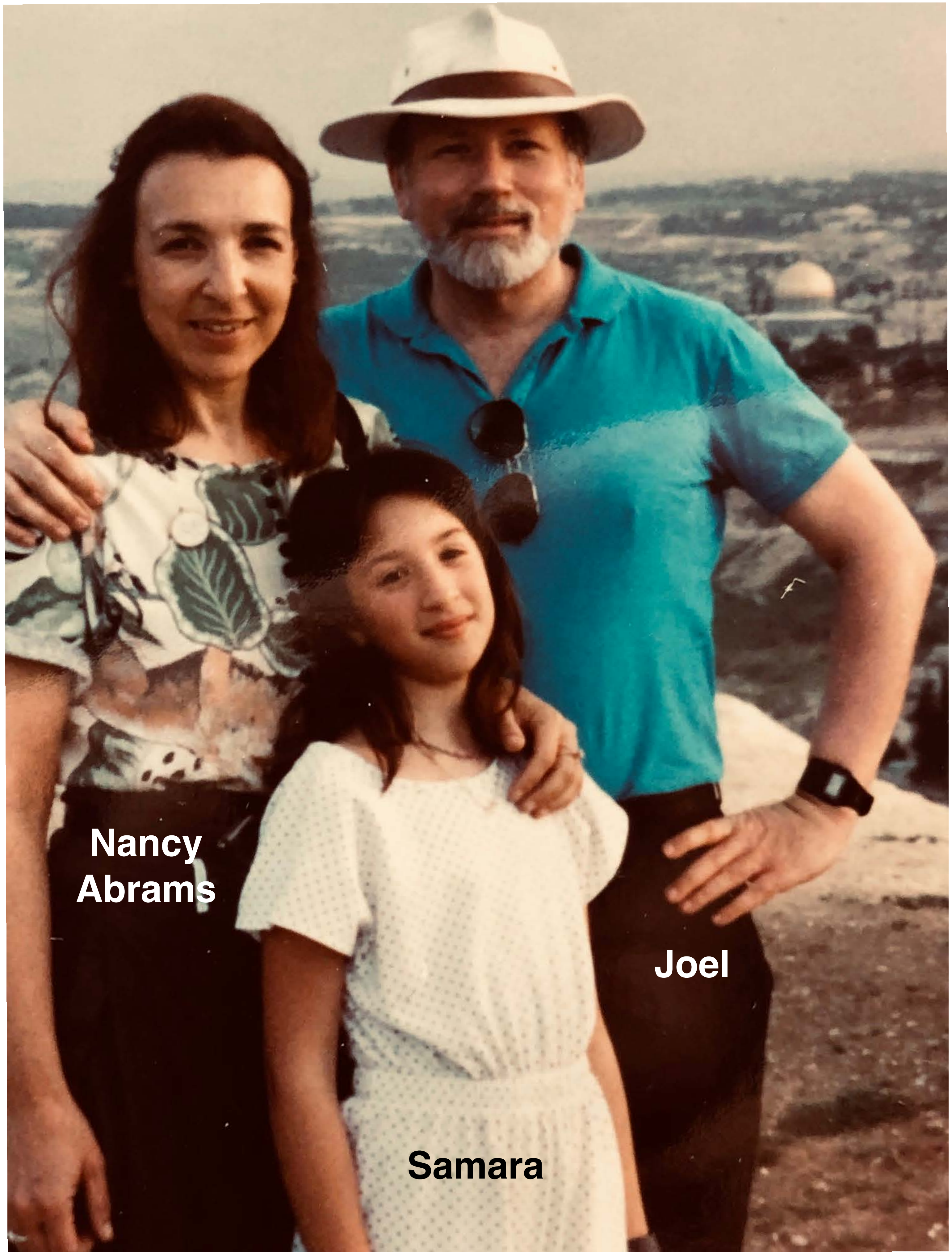
* Lick Observatory, Board of Studies in Astronomy and Astrophysics, University of California, Santa Cruz, California 95064, USA

Joel R. Primack†§ & Martin J. Rees‡§

† Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305, USA
‡ Institute of Theoretical Physics, University of California, Santa Barbara, California 93106, USA

The dark matter that appears to be gravitationally dominant on all scales larger than galactic cores may consist of axions, stable photinos, or other collisionless particles whose velocity dispersion in the early Universe is so small that fluctuations of galactic size or larger are not damped by free streaming. An attractive feature of this cold dark matter hypothesis is its considerable predictive power: the post-recombination fluctuation spectrum is calculable, and it in turn governs the formation of galaxies and clusters. Good agreement with the data is obtained for a Zeldovich ($|\delta_k|^2 \propto k$) spectrum of primordial fluctuations.



Imagining a Cold Dark Matter Universe

Avishai Dekel
Hebrew University

The Pugwash Conferences are an opportunity for scientists from across the world to meet and promote the abolition of weapons of mass destruction. The first one occurred in 1957 in Pugwash, Nova Scotia, in response to a letter from Albert Einstein and Bertrand Russell. Andrei Sakharov's son-in-law Efrem Yankelovich asked me to carry Sakharov's statement to the 25th Pugwash Conference in Warsaw in 1982, calling for decrease of USSR's sphere of influence and for the defense of human rights. I managed to circulate it to all the delegates. Sakharov was then in internal exile in Gorky. Gorbachev freed him in 1986. When Nancy and I went to Moscow in September 1988 to try to stop the USSR from launching nuclear reactors into orbit, we were able to bring some needed supplies to Sakharov and to meet with him and his wife Elena Bonnor in their apartment in Moscow.

Nuclear Satellite To Fall to Earth; Soviet Craft's Threat Debated

Kathy Sawyer, Washington Post May 14, 1988, Saturday

A Soviet satellite powered by a nuclear reactor will fall to Earth late this summer, the Tass news agency acknowledged yesterday. Western experts disputed the Soviets' claim that the craft presents no threat.

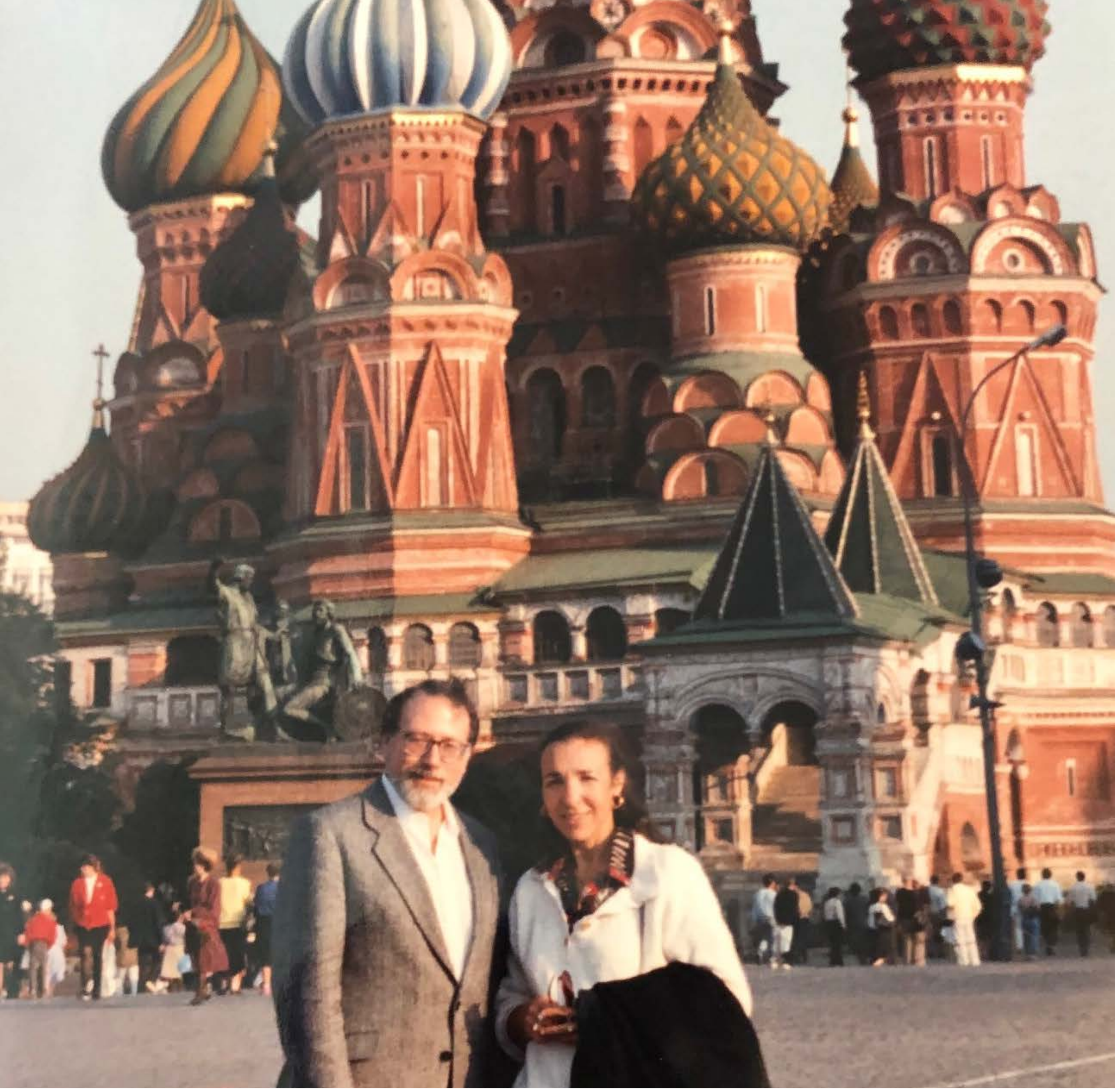
The satellite's safety system, designed to prevent the spread of radioactive debris as occurred in a 1978 incident has malfunctioned, according to scientist Nicholas Johnson of TeledyneBrown Engineering in Colorado Springs, who monitors Soviet space activities.

There is a high probability that the craft will hit an unpopulated area, but the event points up mounting opposition to the use of nuclear power in space.

At a news conference yesterday, prominent Soviet and American scientists called for a ban on nuclear powered craft in Earth orbit. Such a ban would block the Reagan administration's Strategic Defense Initiative, a spacebased missile defense system, as well as the Soviet Union's Radar Ocean Reconnaissance Satellite (RORSAT) program, which is believed to track Western warships.

U.S. officials have been monitoring the falling RORSAT satellite Cosmos 1900, which has been in "a steadily decaying orbit for the last month," according to a spokesman at the U.S. Space Command in Colorado. …

Nuclear power in space is at an early stage, but an estimated 10 to 20 percent of all Soviet and U.S. nuclear space missions have gone awry, according to the Soviet and American scientists at yesterday's briefing.

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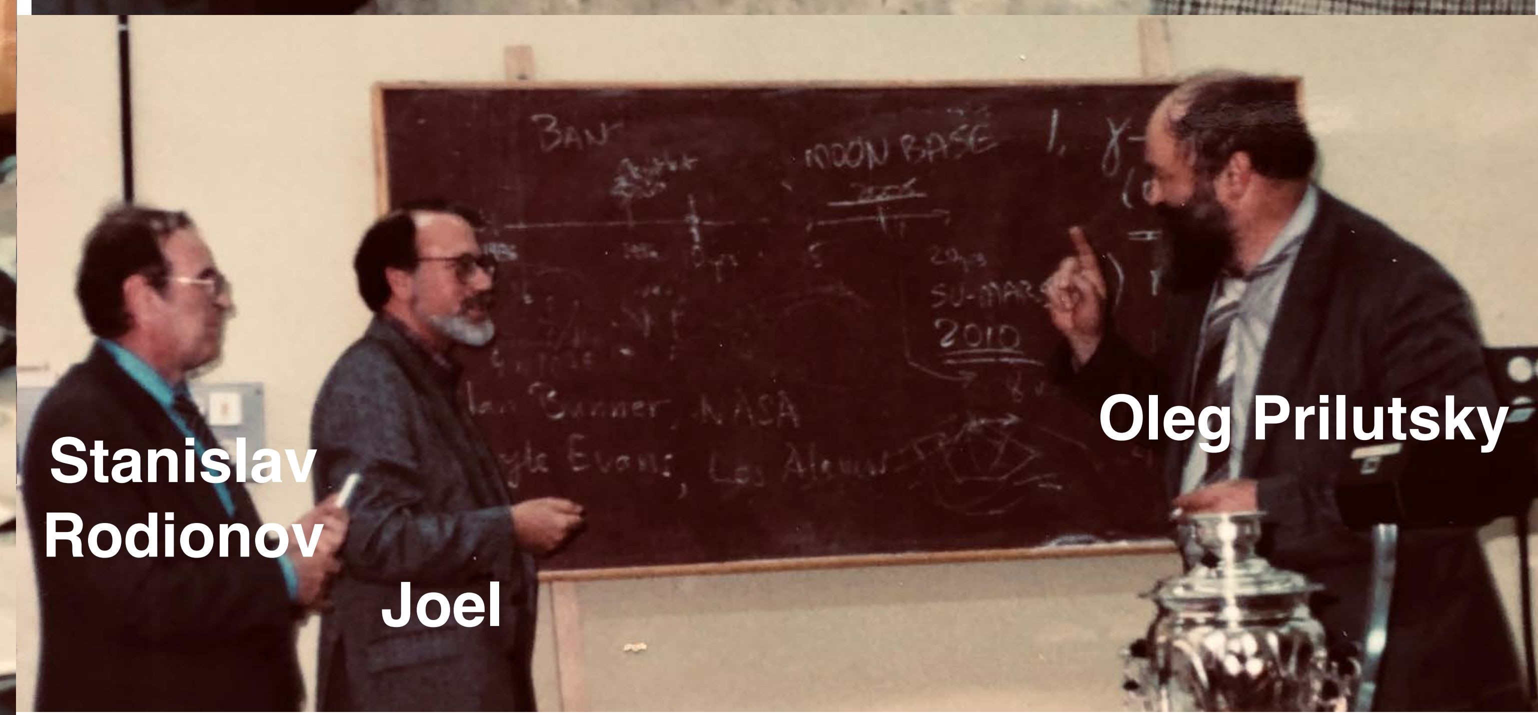

MOON BASE
Stanislav
Rodionov
Joel
Oleg Prilutsky

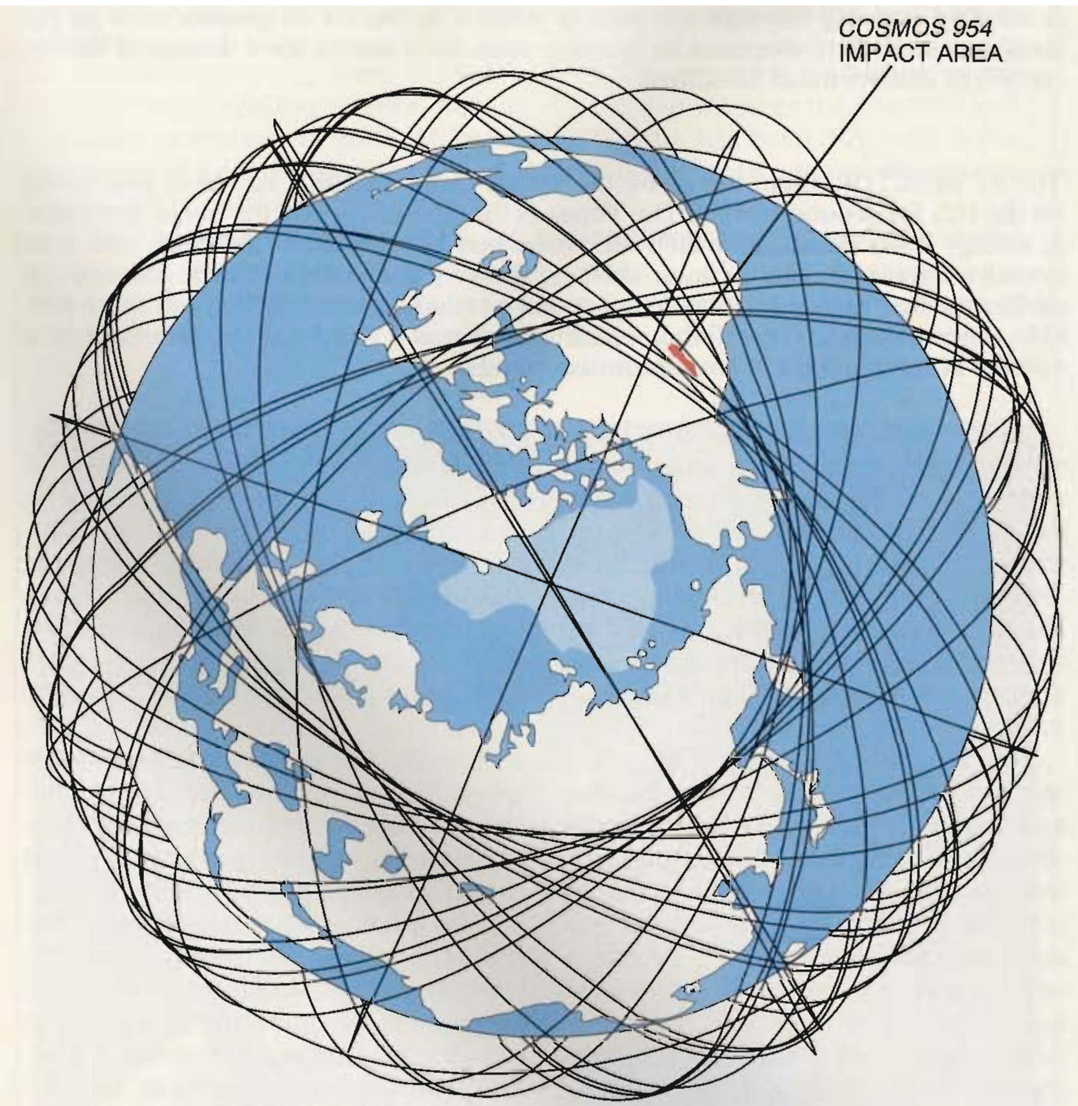
SCIENTIFIC AMERICAN
June 1991

Nuclear Power in Space

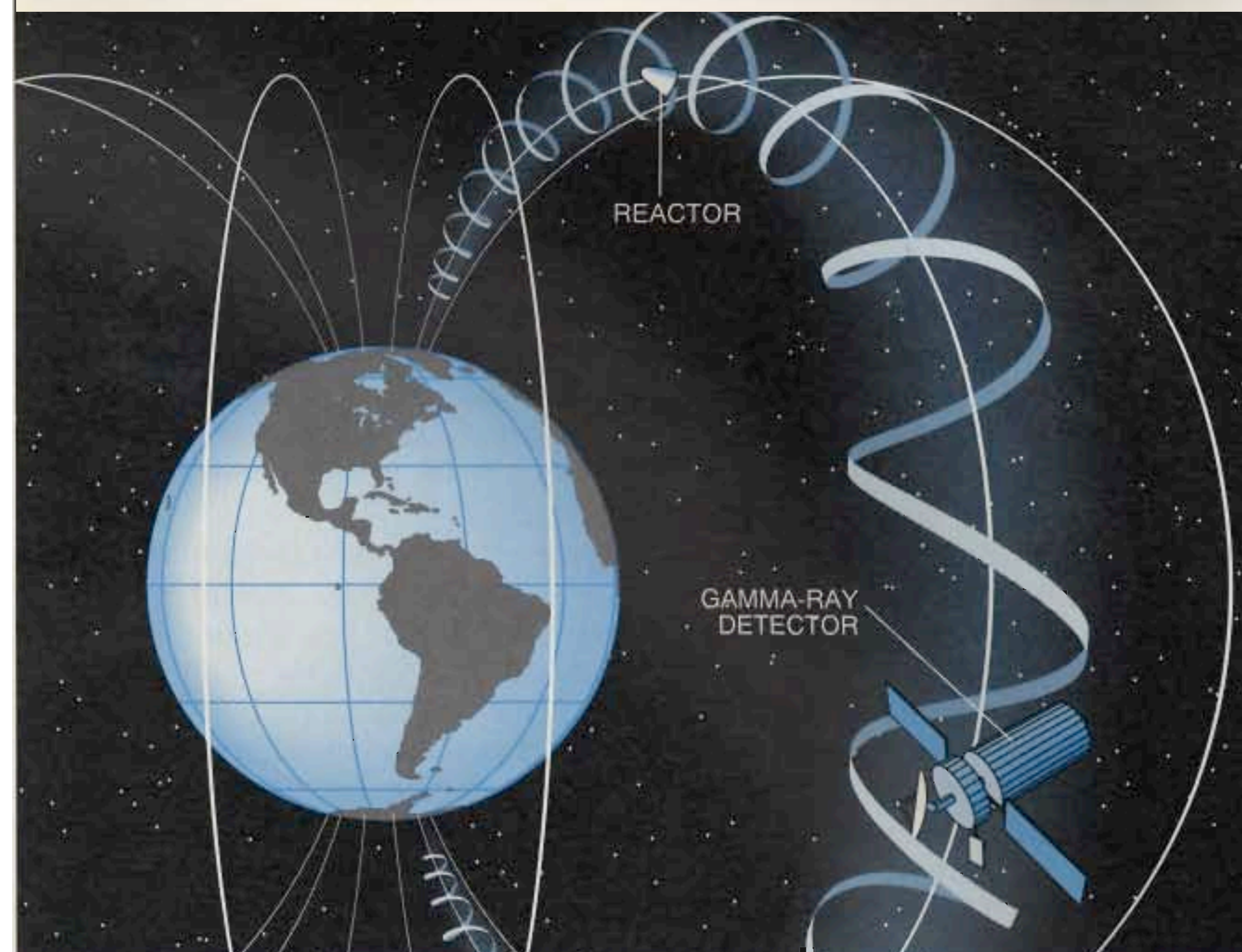
The best course for space-borne reactors? Ban them from Earth orbit and use them in deep space, the authors say

by Steven Aftergood, David W. Hafemeister, Oleg F. Prilutsky, Joel R. Primack and Stanislav N. Rodionov

CLEANING UP AFTER *RORSAT:* a Soviet surveillance satellite (*Cosmos 954*) reentered the earth's atmosphere over the Northwest Territories in 1978, littering radioactive debris over thousands of square miles. In the photographs above, workers gather both large and small fragments of the satellite and its reactor. Decontamination cost the Canadian government approximately $10 million. Proposed U.S. nuclear-powered spacecraft would produce hundreds of times as much radioactivity.



NUCLEAR-POWERED SPACECRAFT successfully deployed in Earth orbit by the U.S. and U.S.S.R. are estimated to number 42. (Two are in distant orbits not shown above.) All the spacecraft, or their jettisoned power supplies, are now in orbits high enough so that they will not reenter the earth's atmosphere until their radioactivity has substantially decayed. Most of them, however, orbit in a region populated with space debris. A collision could send a large number of radioactive fragments along trajectories that would reenter the atmosphere in a few years.



UNSHIELDED ORBITING REACTOR emits a cloud of electrons and positrons that spiral around the earth's magnetic field lines and create a temporary radiation belt. A satellite passing through the belt is subject to bursts of gamma rays as the positrons annihilate electrons in its outer skin. Such bursts have disrupted the operation of astronomical satellites.

In November 1988, at a conference at UCLA on Gamma Ray Astronomy, in addition to presenting a talk reviewing my own research on detecting dark matter, I gave an additional talk "Space Reactors: Signals and Backgrounds." When I explained that space nuclear reactors in orbit would emit gamma rays and positrons, Prof. Stephen White, responded that his group's balloon-borne detectors must have seen these reactors. This was apparently the first public discussion of such detections. My group published many scientific papers and popular articles about space reactors and space debris.

Perspective

Gamma-Ray Observations of Orbiting Nuclear Reactors

JOEL R. PRIMACK

GAMMA RAYS ARE THE MOST ENERGETIC ELECTROMAGNETic radiation, and are produced in some of the least understood objects in the universe such as supernovae, neutron stars, and quasars. Mysterious gamma-ray bursts were first detected in 1967 by the Vela satellites designed to monitor compliance with the ban on nuclear explosions in space. These bursts are thought to be generated by compact astronomical objects—but neither the identities of the sources nor the gamma-ray production mechanisms are yet known. Because gamma rays are extremely penetrating and travel in straight lines, their study may lead us to an understanding of the sources of energetic cosmic rays. The annihilation of the invisible "dark matter" that makes up a majority of the mass of our galaxy may produce gamma rays whose detection will shed light on its composition. Gamma-ray astronomy is still in its infancy, though it is poised for rapid progress with a new generation of satellite instruments to be launched soon.

Four reports (*1–4*) in this issue of *Science* are the first published presentations of observations of nuclear reactors on earth satellites. Three of the reports (*1–3*) discuss observations by the Gamma-Ray Spectrometer (GRS) on the Solar Maximum Mission (SMM) satellite; the other report (*4*) discusses observations by a sensitive gamma-ray telescope carried by a high-altitude balloon. The SMM-GRS observations began in 1980, when SMM was launched, but have only now been declassified. The balloon-borne instrument observed gamma rays from four different reactors during its 30-hour flight over Australia in April 1988.

These observations are important for several reasons. They confirm earlier reports that the Soviet Union has placed many reactors in orbit and provide independent information about the power of these reactors. The observations show clearly that the gamma rays, electrons, and positrons from orbiting reactors are a troublesome background for gamma-ray astronomy. And by demonstrating that orbiting reactors are essentially impossible to hide, these observations may help lay the groundwork for verifying a proposed ban on orbiting reactors—for which there are also compelling environmental and arms control arguments.

The United States orbited a tiny test reactor in 1965. The Soviet Union has subsequently orbited more than 30 reactors of approximately 100-kW thermal power on their Radar Ocean Reconnaissance Satellites (RORSATs), which are used to track U.S. naval vessels (*5*). Since radar power requirements grow rapidly with range, the RORSATs are placed in extraordinarily low orbits of about 250-km altitude where atmospheric drag would prohibit the

The author is a professor at the Institute for Particle Physics, University of California, Santa Cruz, CA 95064.

Science 1989

Science and Global Security, 1989, Volume 1, pp.59–82
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Space Reactor Arms Control

OVERVIEW

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Unshielded nuclear reactors provide the lightest and most survivable long-lived sources of electric power available to support military satellites. Restricting their use now, before a new generation of larger space reactors is tested and deployed by the US and USSR, could help prevent an arms race in space.

Space nuclear power systems have been used by the United States and the Soviet Union since the 1960s. The Soviet Union has used orbiting nuclear reactors to power more than 30 radar ocean reconnaissance satellites (RORSATs). Two RORSATs have accidentally re-entered and released their radioactivity into the environment, and a third, *Cosmos 1900*, narrowly avoided a similar fate.

The United States is developing much more powerful space reactors, of which the SP-100 is farthest along, primarily to power satellite components of the Strategic Defense Initiative (SDI). A working group associated with the Federation of American Scientists (FAS) and the Committee of Soviet Scientists for Peace and Against the Nuclear Threat (CSS) has been studying a proposed ban on orbiting reactors. A proposal by the FAS/CSS group that includes such a ban is attached in the appendix to the Overview.

The first five papers in this section, all by members of the working group, summarize the technological and historical background to nuclear power in space and show that restrictions on orbiting reactors are verifiable. The final paper, by Rosen and Schnyer of NASA, surveys the civilian uses of nuclear power in space.

The overview is a nontechnical introduction to the issues of space reactor arms control, including the proposed ban on orbiting reactors.

Pelted by paint, downed by debris

Missile defenses will put valuable satellites at even greater risk. By Joel Primack

Bulletin of the Atomic Scientists 2002

WE THINK OF SPACE AS EMPTY, BUT THE space near Earth is littered with debris. More than 9,000 objects larger than 10 centimeters in diameter, nearly all manmade, are currently being tracked, and there are probably more than 100,000 pieces of orbiting debris larger than a marble.[1] Yet the crowded near-Earth orbits inhabited by this debris are where the Bush administration wants to put certain parts of its proposed missile defense system—Space-Based Lasers and thousands of "Brilliant Pebbles" space-based interceptor missiles. These weapons were previously forbidden by the 1972 Anti-Ballistic Missile (ABM) Treaty, which the United States withdrew from in June.

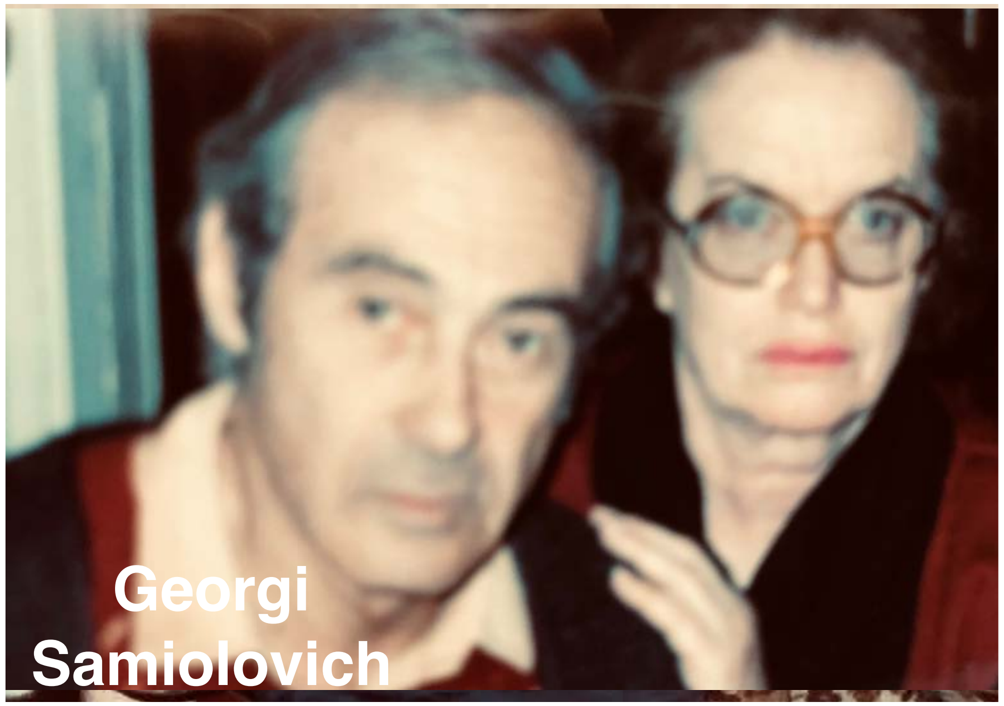
Weaponization of space would make the debris problem much worse, and even one war in space could encase the entire planet in a shell of whizzing debris that would thereafter make space near the Earth highly hazardous for peaceful as well as military purposes.

The nickname "Star Wars" for missile defense all too accurately reflects the popular fantasy about how things work in space. In the *Star Wars* movies and in hundreds of other popular science fiction films, we see things blow up in space and the fragmarble traveling at such speed would hit with the energy of a one-ton safe dropped from a three-story building. Anything it strikes will be destroyed and only increase the debris.

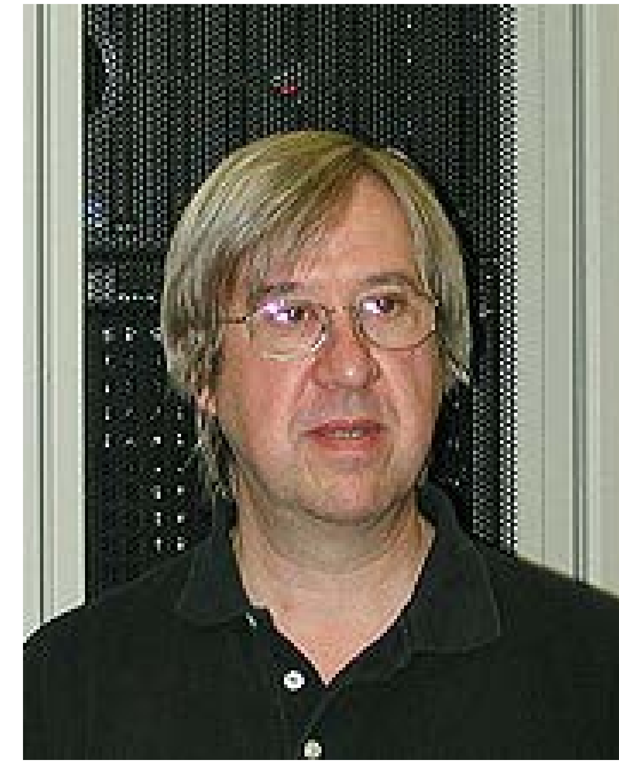
With enough orbiting debris, pieces will begin to hit other pieces, fragmenting them into more pieces, which will in turn hit more pieces, setting off a chain reaction of destruction that will leave a lethal halo around the Earth. To operate a satellite within this cloud of millions of tiny missiles would be impossible: no more Hubble Space Telescopes or International Space Stations. Even communications and GPS satellites in higher orbits would be endangered. Every person who cares about the human future in space should also realize that weaponizing space will jeopardize the possibility of space exploration.

TO A SCIENTIST WHOSE RESEARCH HAS BENEFITED enormously from space observations, these prospects are horrifying. Many of the important astronomical satellites are in low Earth orbit (from the lowest practical orbits—about 300 kilometers—to about 2,000 kilometers above the Earth). The Cosmic Background Explorer, which operated from

While we were in Moscow, Nancy and I met with a group of "refuseniks" (Jewish scientists who had been refused permission to emigrate and were fired from their jobs). We were able to arrange for two of these families to emigrate with Senator Ted Kennedy's help.



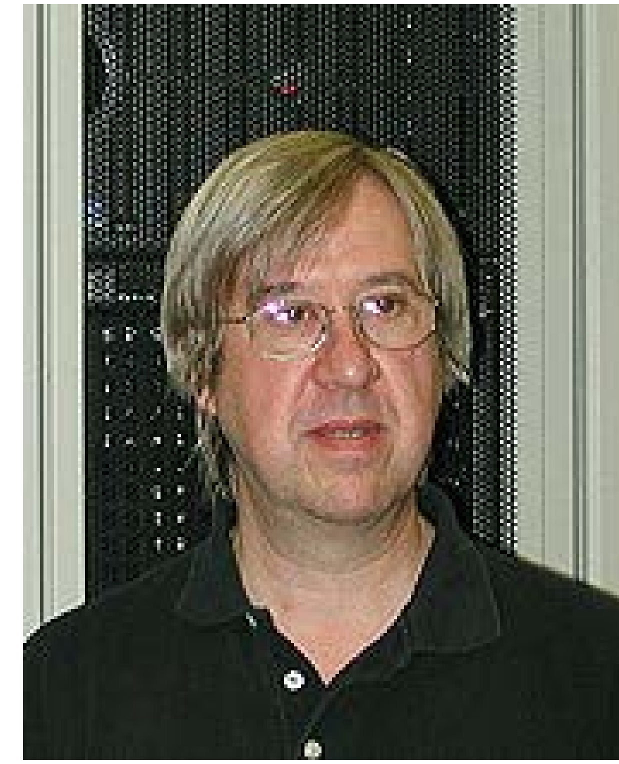
Alex Szalay
Astrophysicist
& Musician



In 1983 Alex Szalay did some of the first calculations of the new CDM cosmology, and we became friends. In 1987 Alex organized an informal meeting in Budapest where I met many of the top Russian astrophysicists whom I saw again in Moscow in 1988, although Jacob Zel'dovich had meanwhile died.

Joel also gave lectures in Moscow about his astrophysics research and initiated research programs with two Russian astrophysicists, Lev Kofman and Anatoly Klypin, that subsequently led to many significant research papers. Sadly, Lev Kofman died very young of cancer. Anatoly Klypin, now a professor of astronomy at New Mexico State University and the University of Virginia, has been one of Joel's main research partners for the past 25 years; they have run some of the largest cosmological simulations and published over 65 papers.

Alex Szalay
Astrophysicist & Musician



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When my **pancreatic cancer** metastasized to my liver in December 2018 and chemotherapy didn't help, my oncologist asked if I had any friends at Johns Hopkins, where they were pioneering cancer immunotherapy. Alex Szalay told me that he was spending half his time helping the immuno-therapists with their software, and he asked the head of the program to help me. **This Phase 1 immunotherapy drug trial appears to have cured me!**

A Brief History of Dark Matter

1930s - Zwicky discovers galaxy cluster are mostly “dark matter”

1970s - Vera Rubin discovers that galaxies are mostly dark matter

1980s - Most astronomers are convinced that dark matter is most of the mass of galaxies and clusters

1980-84 - Short life of Hot Dark Matter theory

1983-84 - Cold Dark Matter (CDM) theory of galaxy formation

1992 - COBE discovers big bang temperature fluctuations as predicted by CDM; CHDM and ΛCDM are favored variants

1998 - Supernovae and other evidence of Dark Energy

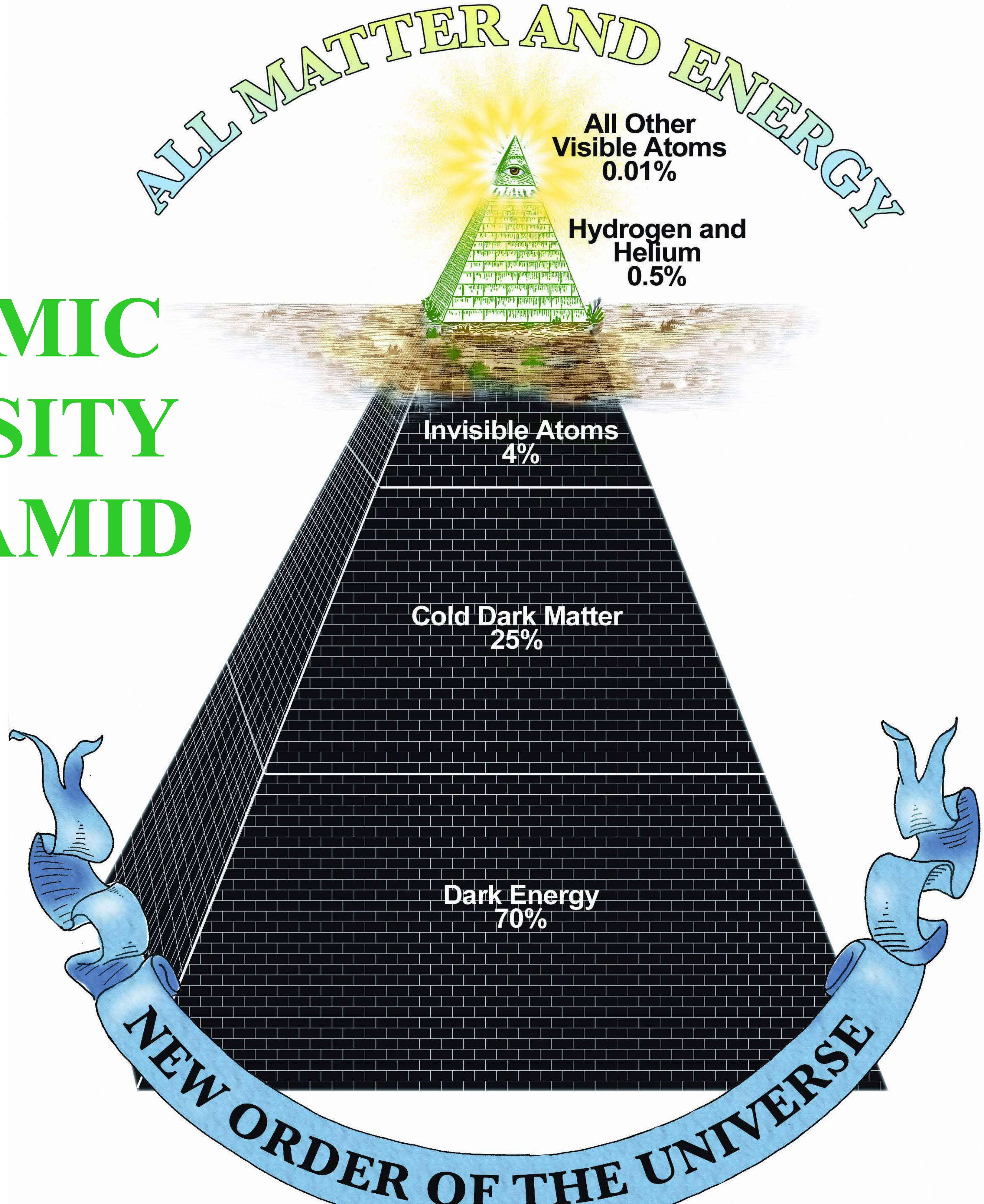
2000 - ΛCDM is the Standard Cosmological Model

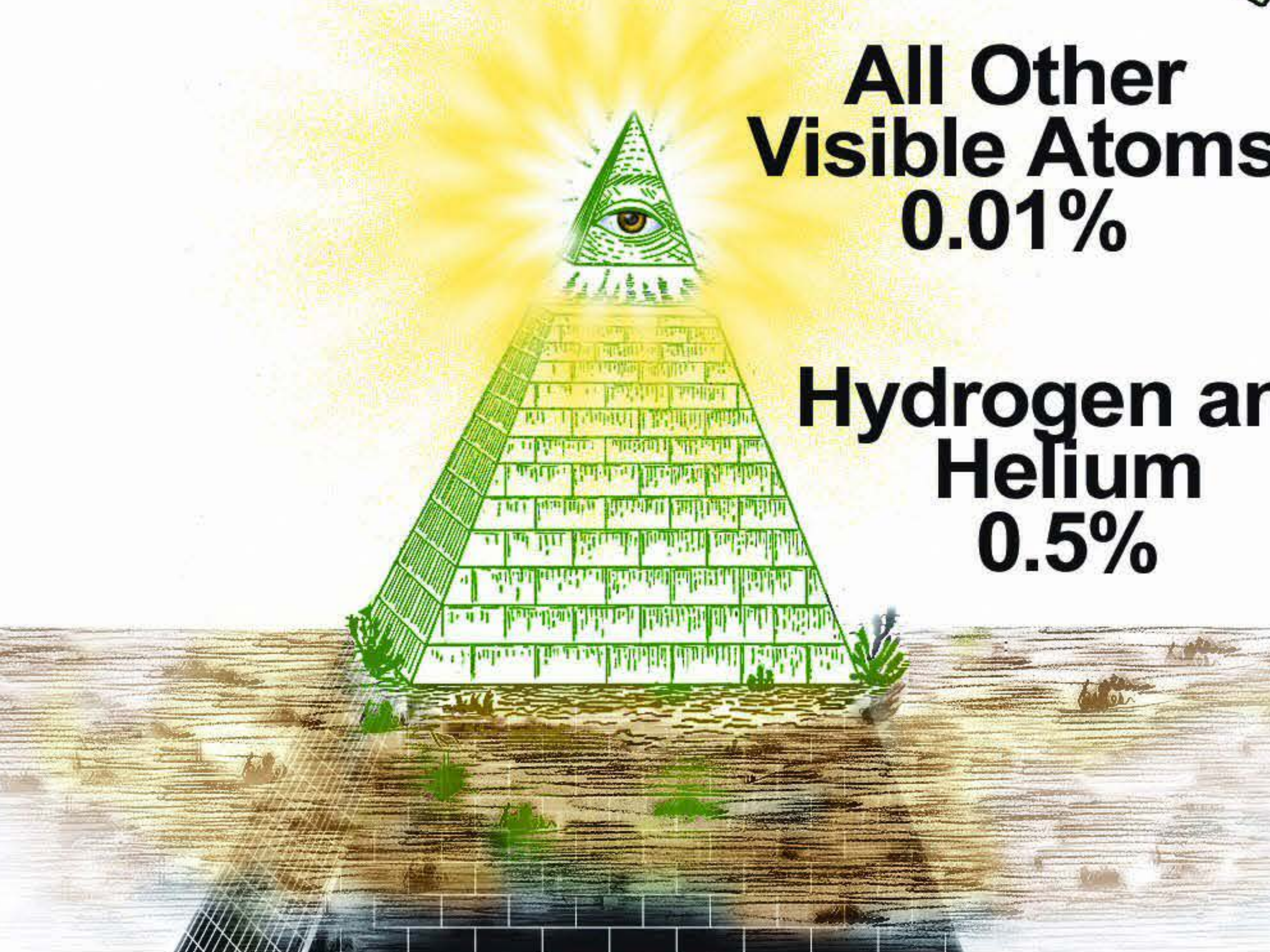
2003 - WMAP, Planck, and LSS confirm ΛCDM predictions

~2022 - Discovery of dark matter particles??


Hubble Space Telescope Ultra Deep Field - ACS
This picture is beautiful but misleading, since it only shows about 0.5% of the cosmic density.
The other 99.5% of the universe is dark.

COSMIC DENSITY PYRAMID

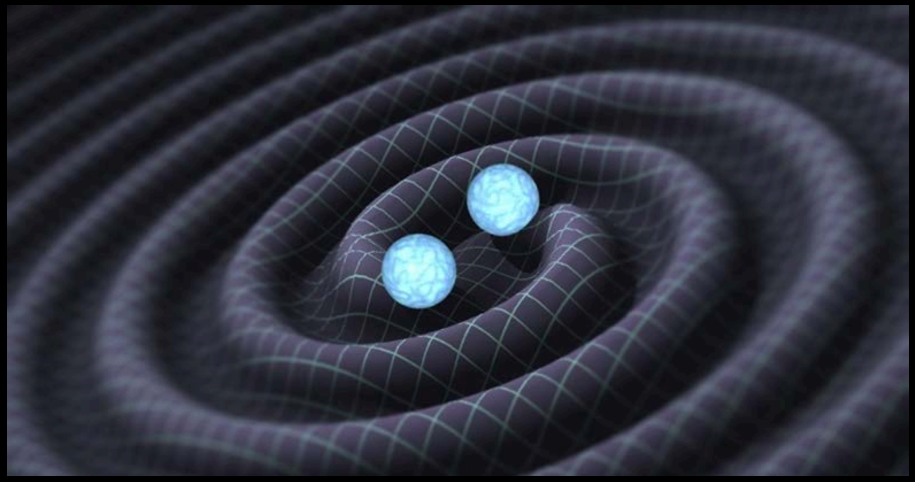


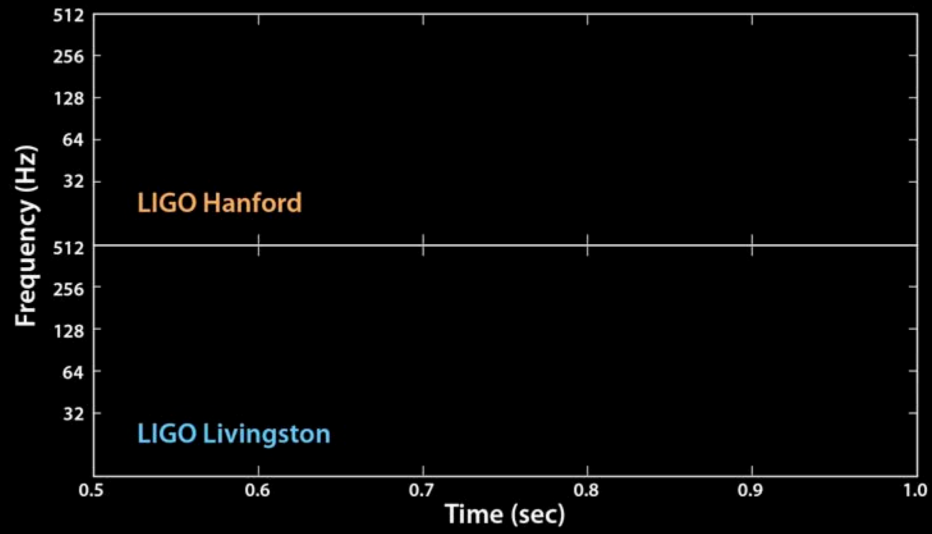

All Other
Visible Atoms
0.01%
Hydrogen ar
Helium
0.5%

stardust

first stars

Many stars in the very early universe may have been much more massive than our sun, in binary star systems with other massive stars. When these stars ended their lives as supernovas, they became massive black holes. The Laser Interferometer Gravitational-wave Observatory (LIGO) has now detected > 50 mergers of massive black holes. This confirmed predictions of Einstein's general relativity that had never been tested before.





In August 2017 LIGO and VIRGO announced the discovery of gravity waves from merging neutron stars. Data from telescopes shows that such events probably generate most of the heavy elements like europium, gold, thorium, and uranium.

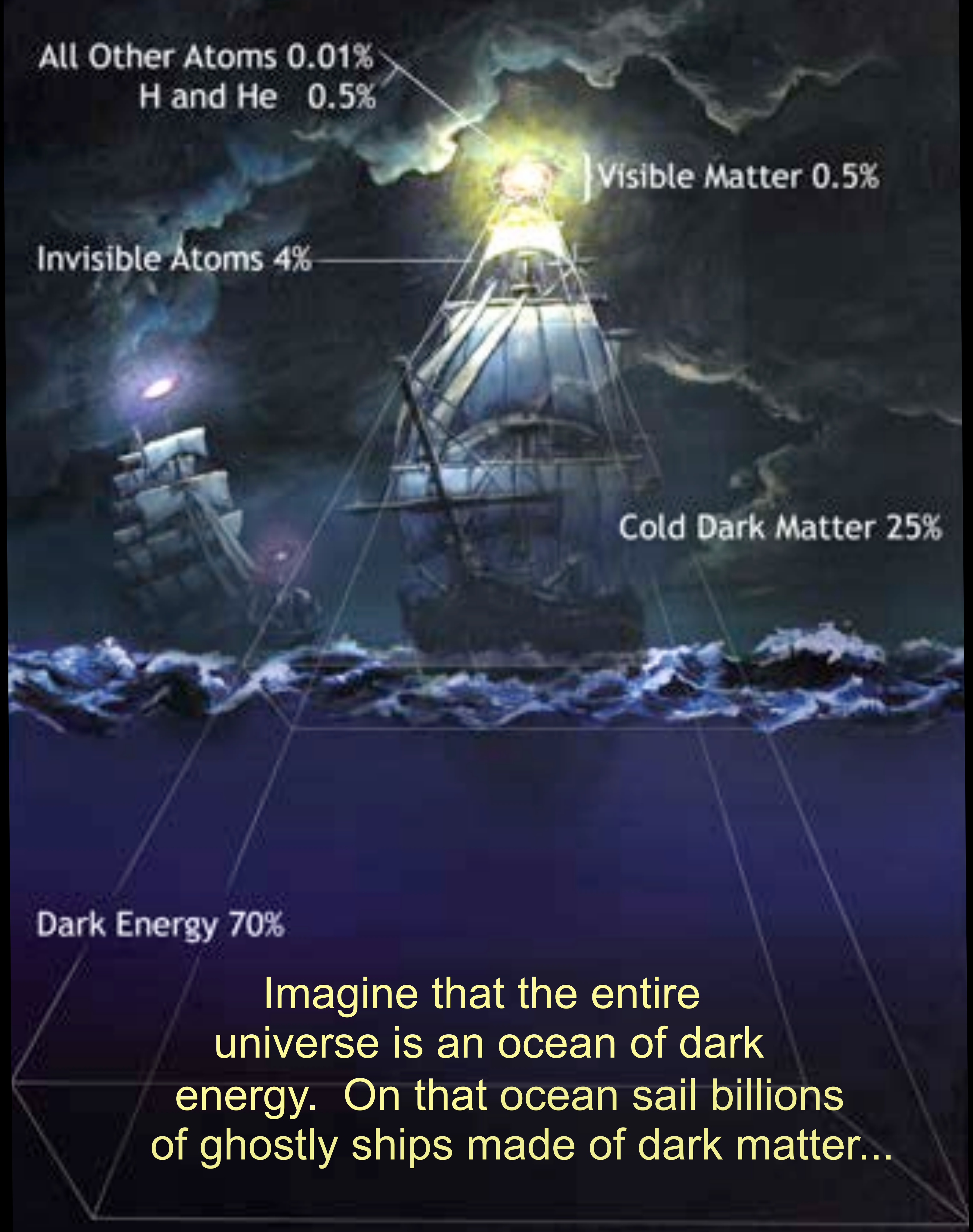
Periodic Table of the Elements

(Jennifer Johnson)

Dark Matter Ships

on a

Dark Energy Ocean

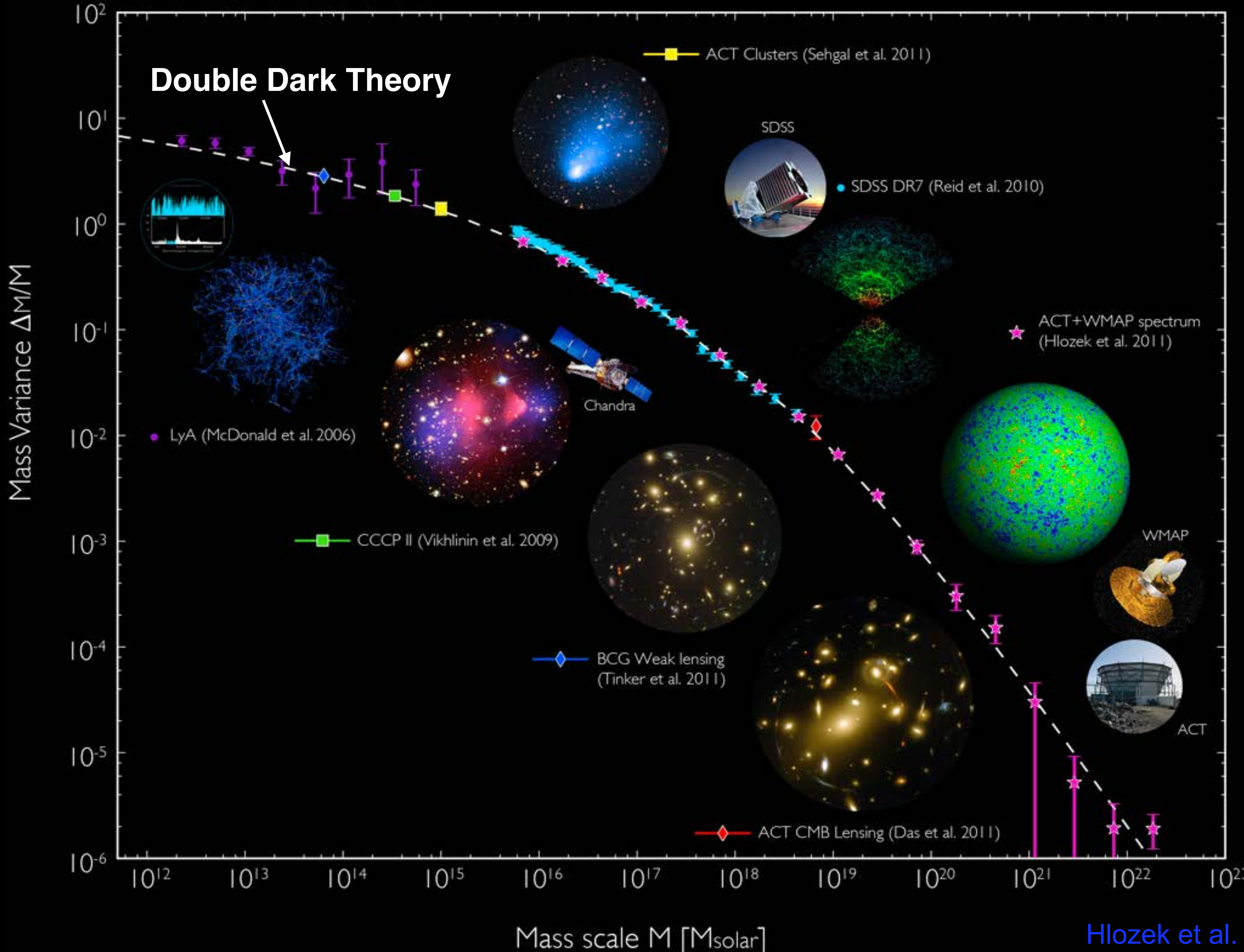


Matter and Energy Content of the Universe

ΛCDM

Double Dark Theory

Matter Distribution Agrees with Double Dark Theory!

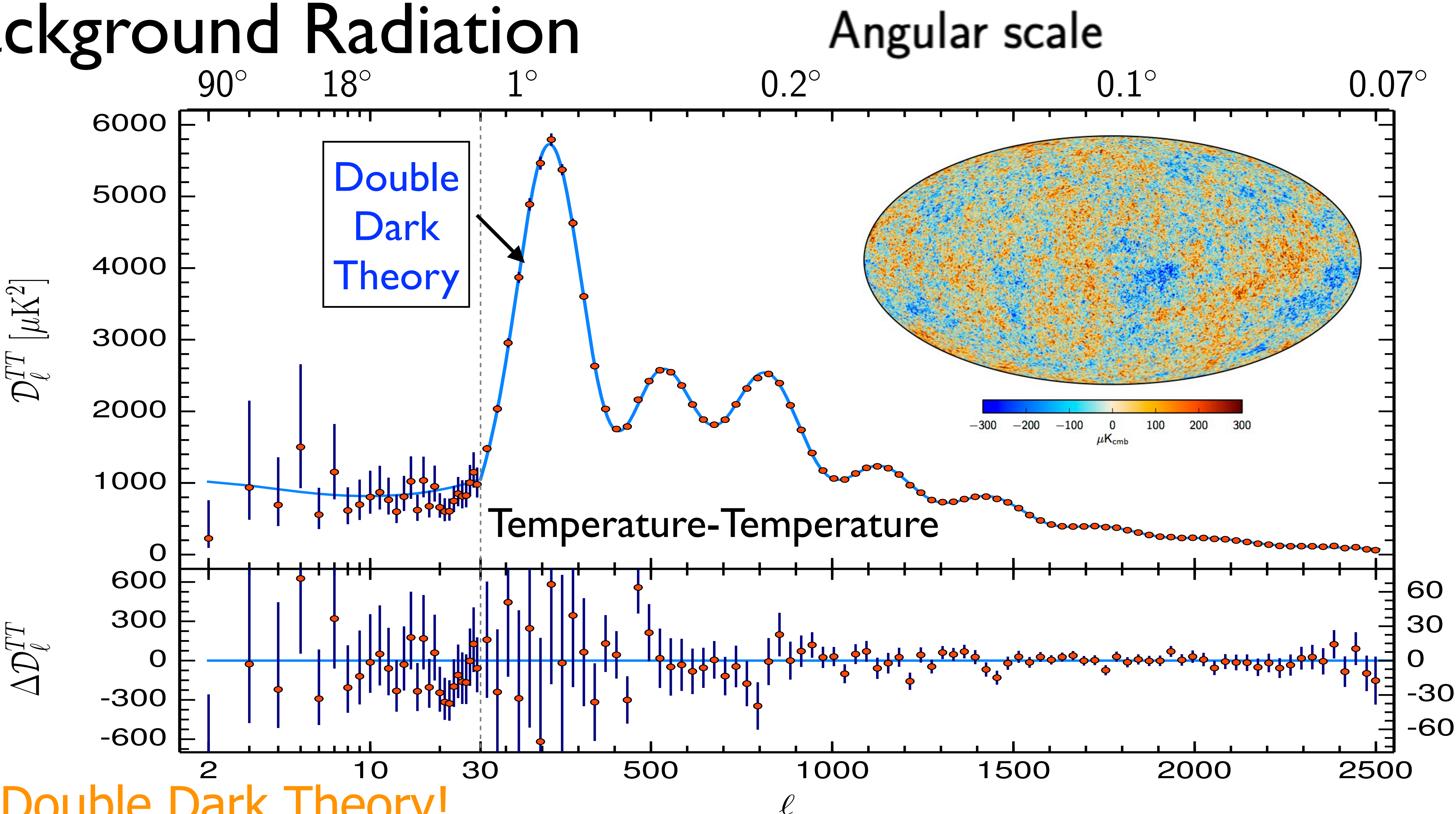


Hlozek et al. 2012

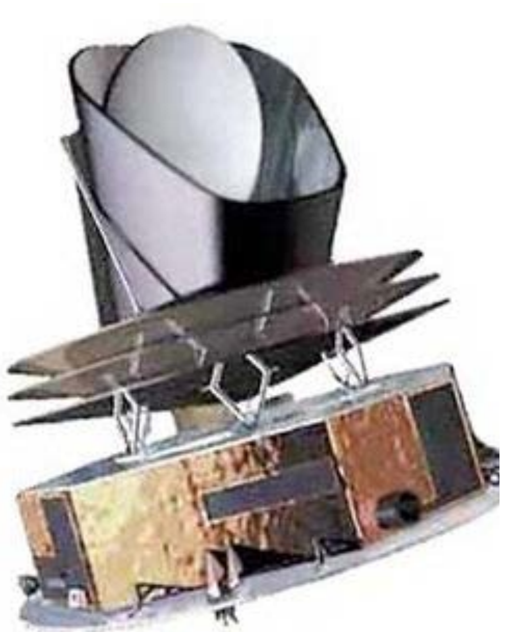
Cosmic Background Radiation

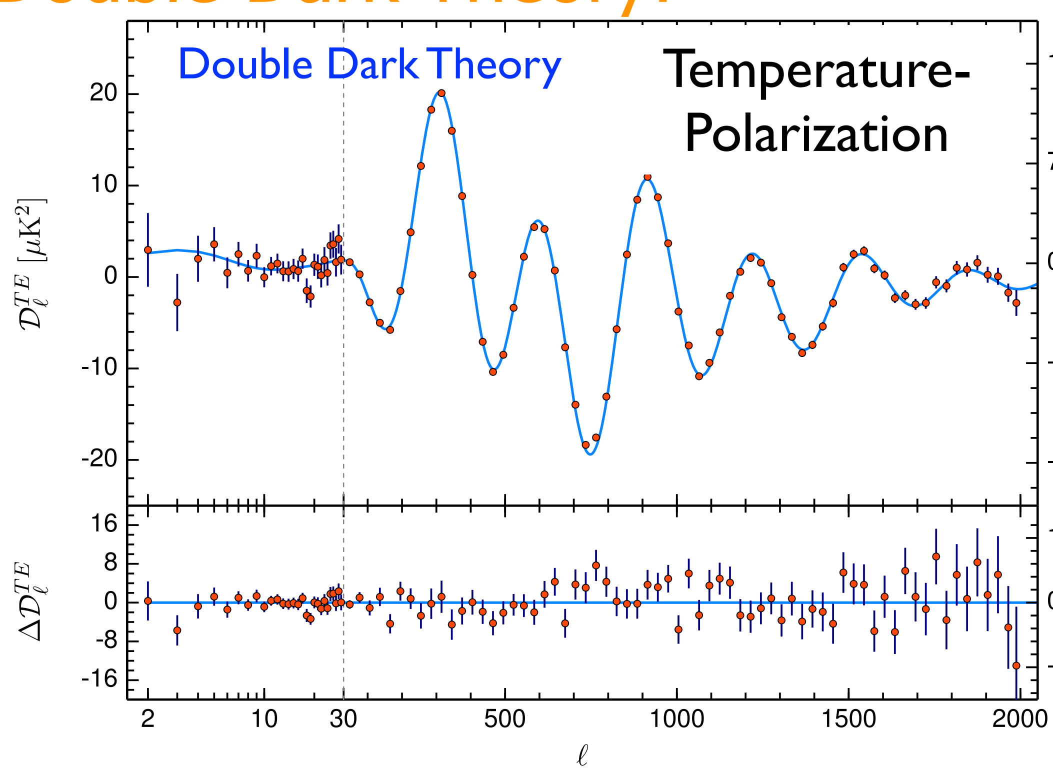
European Space Agency PLANCK Satellite Data

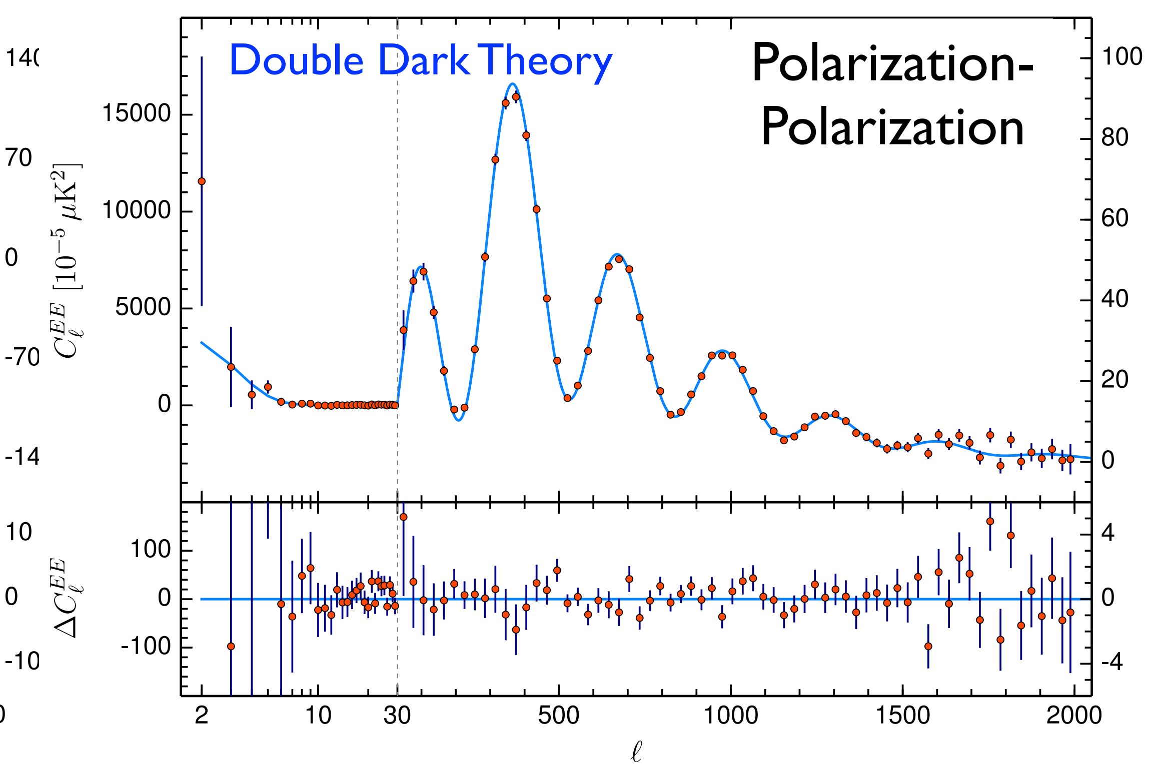
Released September 24, 2019



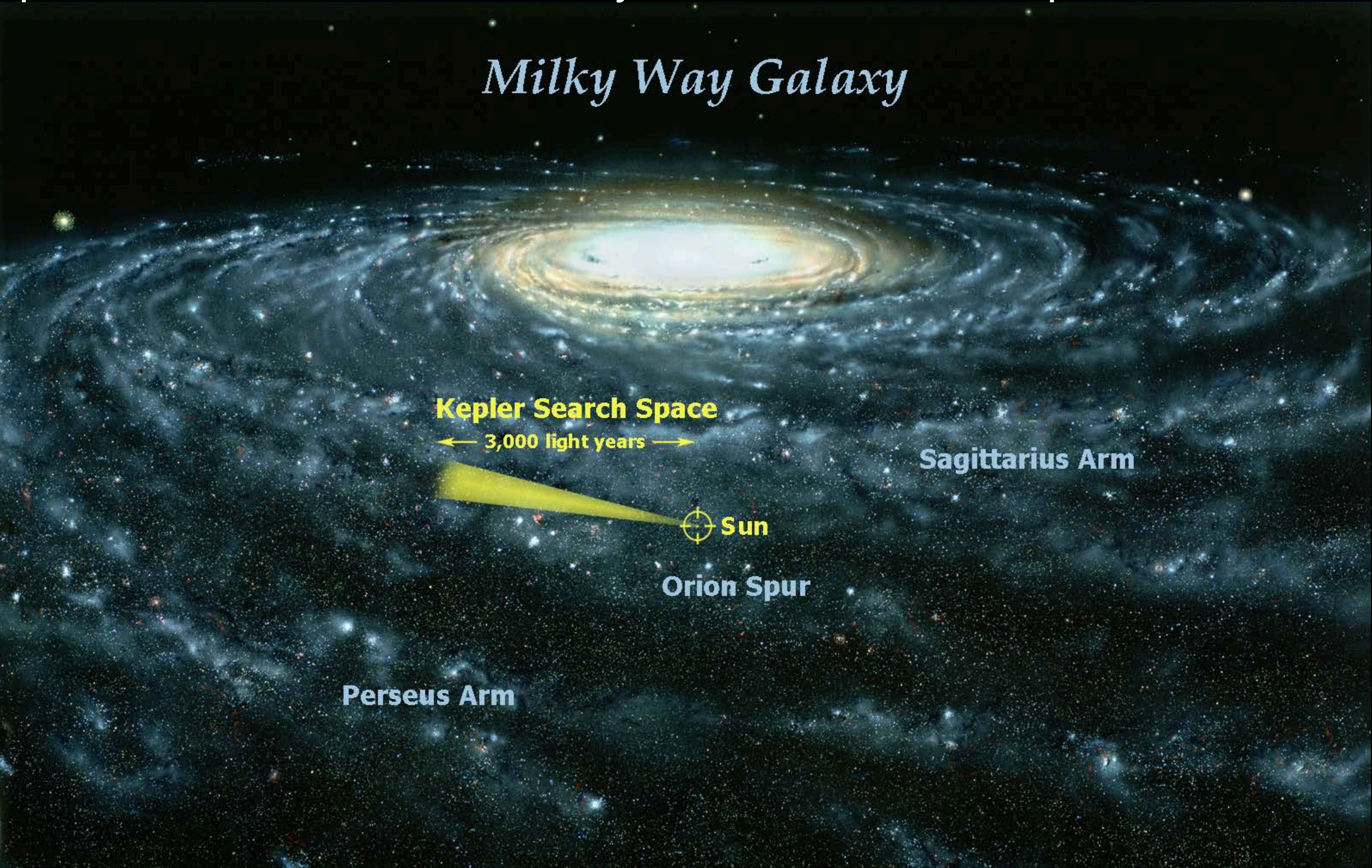
Agrees with Double Dark Theory!



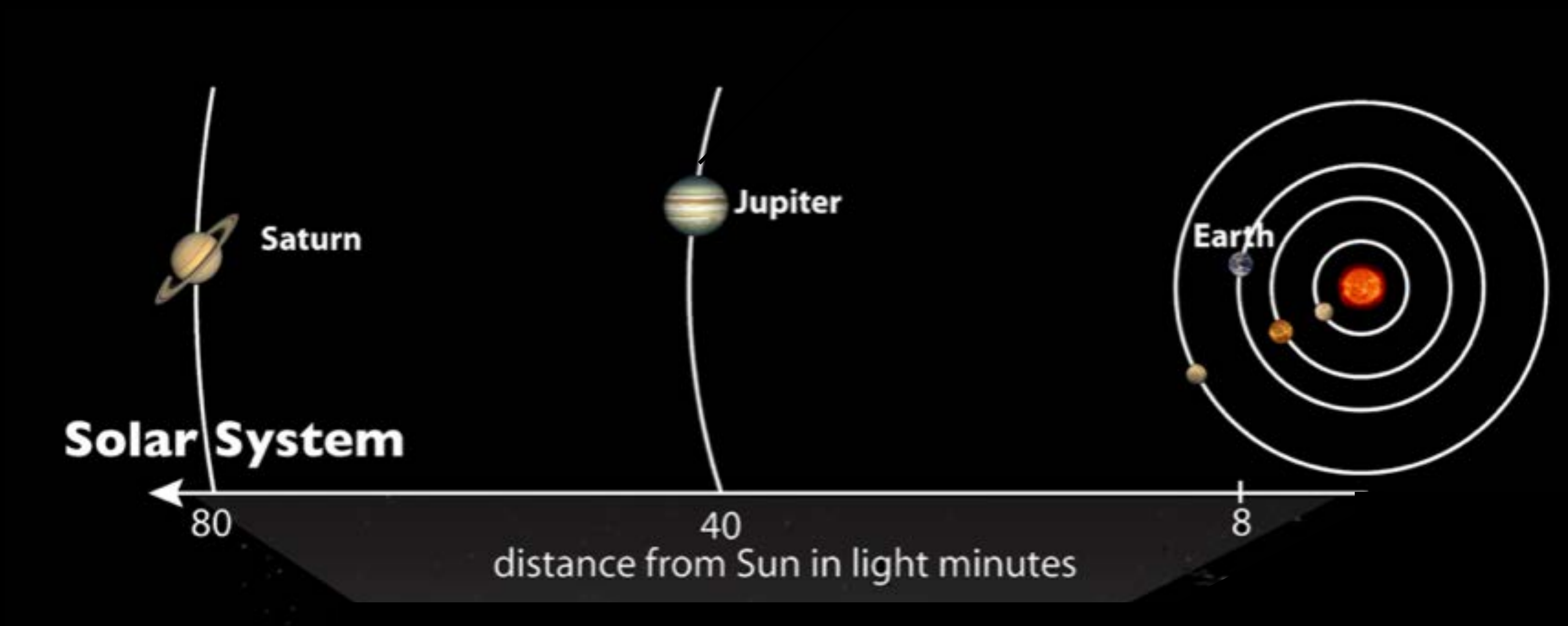




We have now discovered about 4000 planetary systems, mainly using star radial velocities from ground-based telescopes and planet-star transits observed by NASA's satellites Kepler and TESS.



We used to think that our system is typical, with rocky planets near our star and gas giants farther away.



Of the ~ 4000 planetary systems astronomers have discovered, there are very few like ours, with all the planets widely spaced in nearly circular orbits. Most planetary systems are much smaller.

The most common type of planet seems to be 2 to 6 times Earth's mass, a "**super-Earth**". No such planet exists in our Solar System.

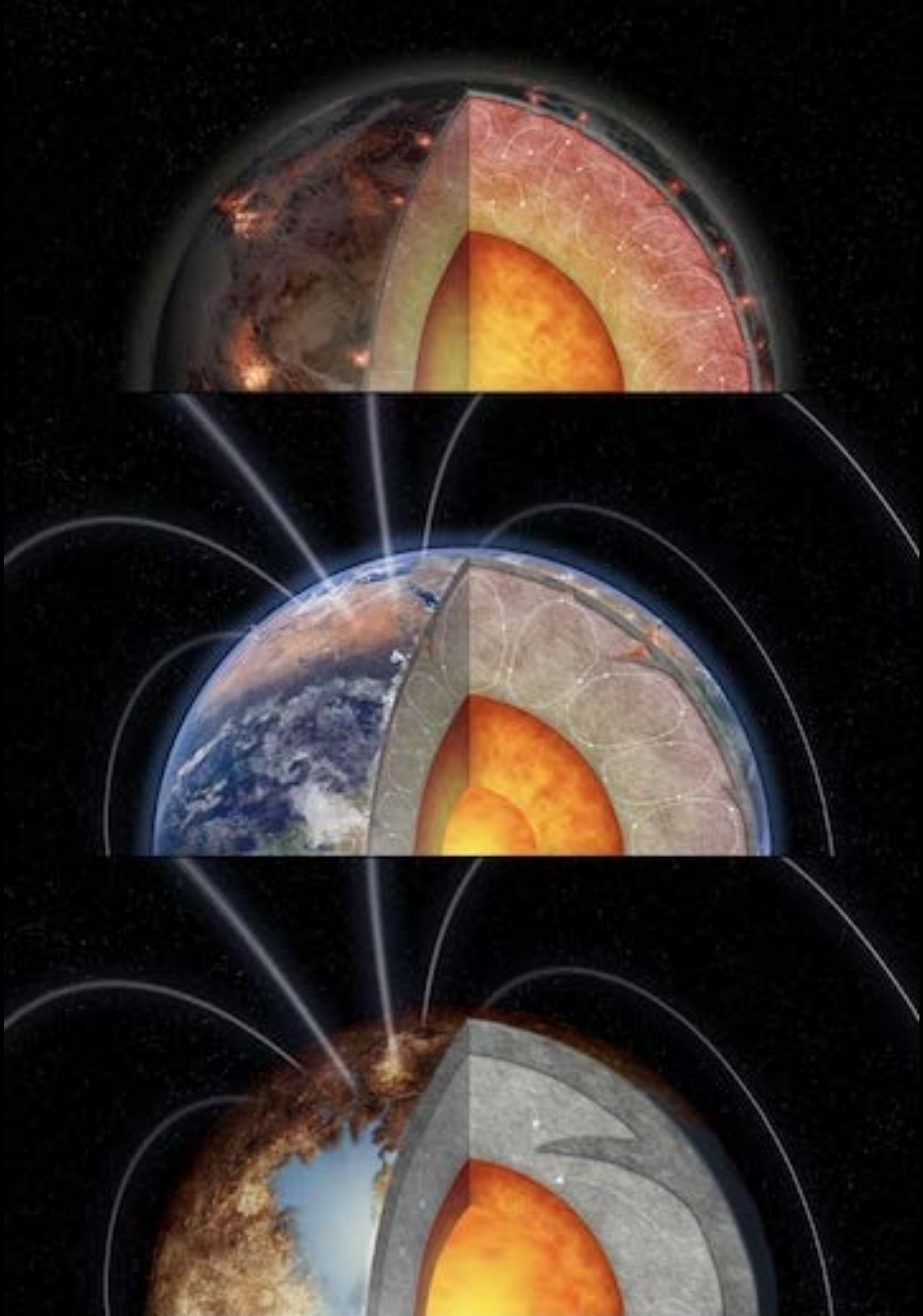
Some planets are in the **habitable zone around their stars** in which water would be in liquid form, but most of these planets are probably not hospitable to advanced forms of life. For one thing, they might not have an optimal abundance of the long-lived radioactive elements thorium and uranium to power plate tectonics and permit a magnetic dynamo. Too much Th and U would result in a lava world with frequent flood vulcanism, which caused the greatest mass extinction events on Earth. **Our living Earth may be a rare "Goldilocks" planet** with just the right amount of Th and U.

There may be **galactic habitable zones** — not too close to galaxy centers where there are frequent supernovae and AGN outbursts, nor too far where heavy elements may be too rare to form rocky planets.

3x Earth's Th and U
No magnetic dynamo &
frequent flood vulcanism

Earth's Th and U
Magnetic dynamo &
plate tectonics

⅓ Earth's Th and U
Magnetic dynamo
but no plate tectonics



Periodic Table of the Elements

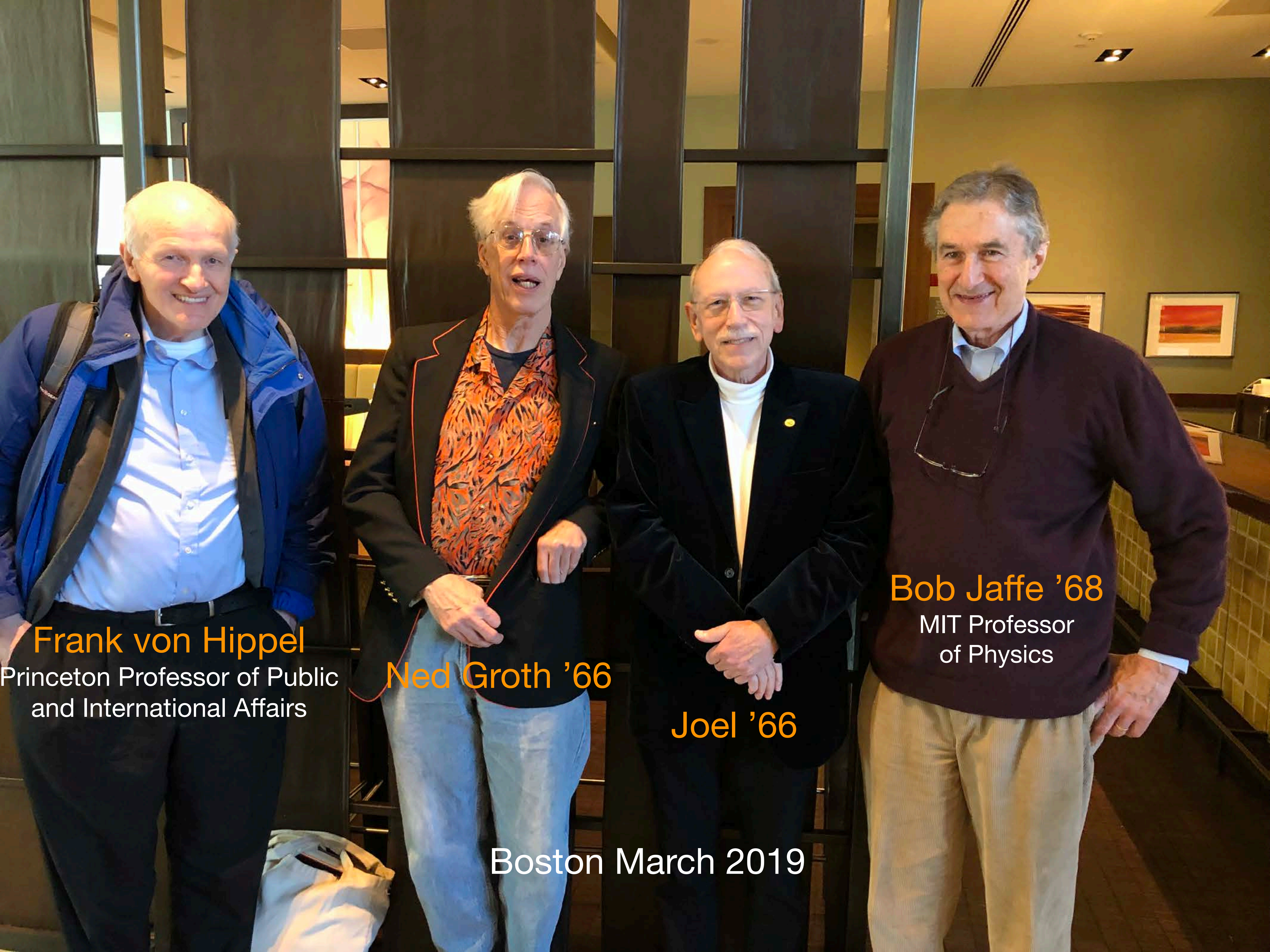
Uranium and Me

My Princeton senior thesis - modern nuclear fission theory
Working with Henry Kendall and Freeman Dyson on reactor safety
Starting the American Physical Society Reactor Safety study
Nancy's scientific mediation on Swedish nuclear waste disposal
Pugwash Conferences on ending weapons of mass destruction
Stopping orbiting nuclear reactors - RORSATs and Star Wars
Energy courses at UCSC, including with Ted Taylor
Three Mile Island - serving on the NRC study
Earth is a radioactively Goldilocks planet:

"the first good thing I ever heard about uranium"

Mixing Science and Politics

has enriched them both for me


Frank von Hippel
Princeton Professor of Public
and International Affairs
Ned Groth '66
Joel '66
Bob Jaffe '68
MIT Professor
of Physics
Boston March 2019

When the Milky Way Merges with the Andromeda Galaxy simulation visualization - with music by Nancy Abrams

Thanks!