

The Kavli Institute for Cosmological Physics: the first 40 years

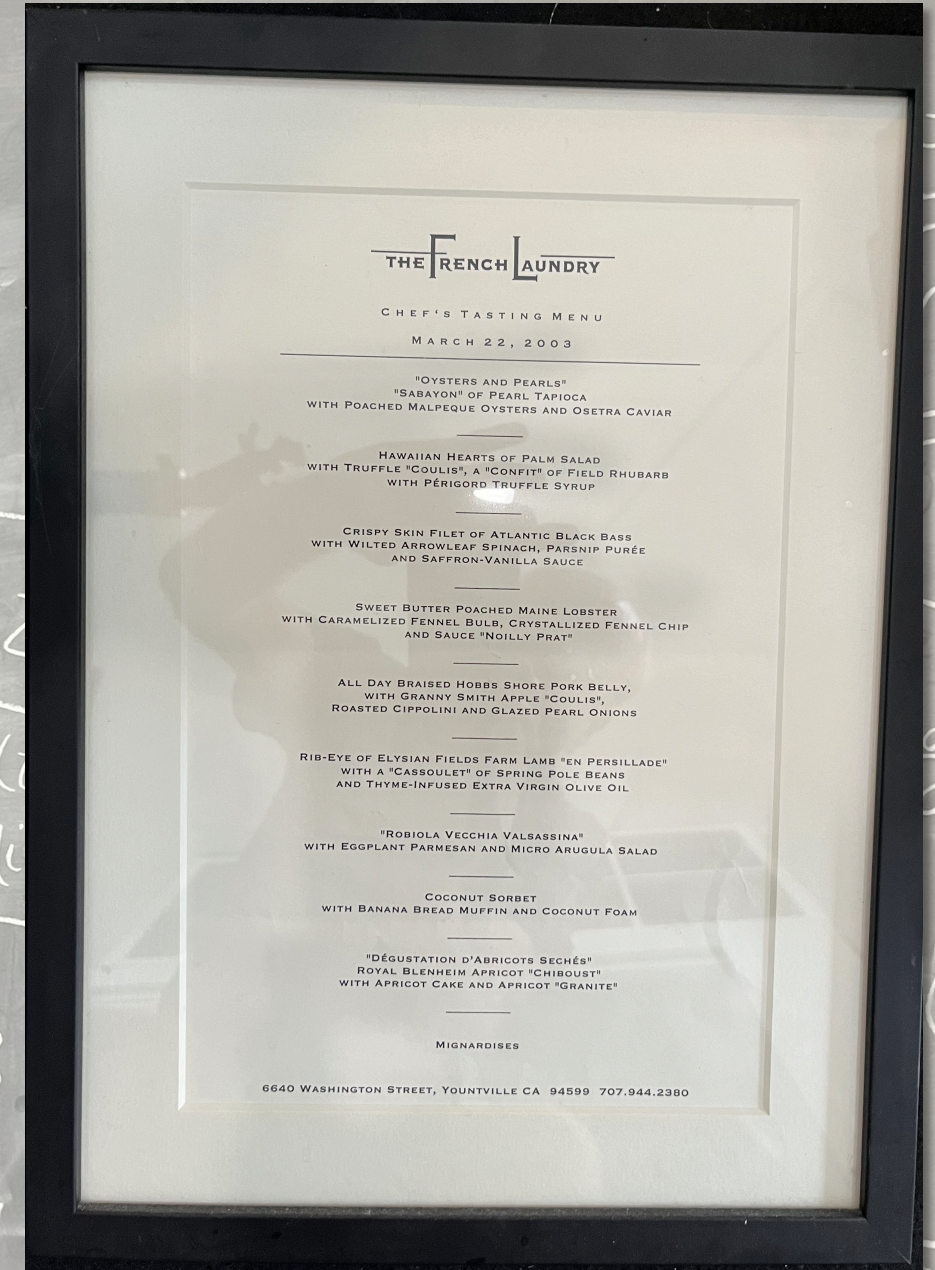
Some history, greatest hits (to date!), the future
“embrace the complexity”

Michael S. Turner

Kavli Institute for Cosmological Physics (2004 –)

8 June 2024

KICP origins, part 1: 2003/04



THE FRENCH LAUNDRY

CHEF'S TASTING MENU
MARCH 22, 2003

"OYSTERS AND PEARLS"
"SABAYON" OF PEARL TAPIOCA
WITH POACHED MALPEQUE OYSTERS AND OSETRA CAVIAR

HAWAIIAN HEARTS OF PALM SALAD
WITH TRUFFLE "COULIS", A "CONFIT" OF FIELD RHUBARB
WITH PÉRIGORD TRUFFLE SYRUP

CRISPY SKIN FILET OF ATLANTIC BLACK BASS
WITH WILTED ARROWLEAF SPINACH, PARSNIP PURÉE
AND SAFFRON-VANILLA SAUCE

SWEET BUTTER POACHED MAINE LOBSTER
WITH CARAMELIZED FENNEL BULB, CRYSTALLIZED FENNEL CHIP
AND SAUCE "NOILLY PRAT"

ALL DAY BRAISED HOBBS SHORE PORK BELLY,
WITH GRANNY SMITH APPLE "COULIS",
ROASTED CIPPOLINI AND GLAZED PEARL ONIONS

RIB-EYE OF ELYSIAN FIELDS FARM LAMB "EN PERSILLADE"
WITH A "CASSOULET" OF SPRING POLE BEANS
AND THYME-INFUSED EXTRA VIRGIN OLIVE OIL

"ROBIOLA VECCHIA VALSASSINA"
WITH EGGPLANT PARMESAN AND MICRO ARUGULA SALAD

COCONUT SORBET
WITH BANANA BREAD MUFFIN AND COCONUT FOAM

"DÉGUSTATION D'ABRICOTS SECHÉS"
ROYAL BLENHEIM APRICOT "CHIBOUST"
WITH APRICOT CAKE AND APRICOT "GRANITE"

MIGNARDISES

6640 WASHINGTON STREET, YOUNTVILLE CA 94599 707.944.2380

PLEDGE AND GRANT AGREEMENT

The Kavli Institute for Cosmological Physics at the University of Chicago

In consideration of Mr. Fred Kavli making a pledge and the Kavli Foundation ("the Foundation") making a grant in the aggregate sum of \$7,500,000, to the undersigned, The Board of Trustees of The University of Chicago ("The University"), and as an inducement to the consummation of such pledge and grant, the Foundation, Fred Kavli and The University agree to the following terms and conditions:

1. Use of Pledge and Grant Proceeds.

The amount transferred in payment of this pledge and grant commitment may, for investment purposes, be merged with any of the investment assets of The University, but they shall be entered in The University's books and records initially as THE FRED KAVLI FUND ("the Fund"). The purpose of the Fund is to establish, name and endow The Kavli Institute for Cosmological Physics at the University of Chicago (the "Institute"). One million dollars of the Fund shall be used as seed funding for an ultra-sensitive polarimeter to enable cosmic microwave background radiation measurements with the South Pole Telescope. The remainder of The Fund will be used to establish an endowment, proceeds of which will be distributed on an annual basis in support of the programs of the Institute according to University policy.

The mission of the Kavli Institute for Cosmological Physics is to deepen our understanding of the origin and evolution of the Universe and the laws that govern it by bringing together astronomers and physicists within a unique interdisciplinary culture. The Institute is envisaged to be an inclusive program, broadly supporting cosmological physics University-wide; it will nurture the intellectual range of activities at the University and promote scholarly communication and research activities engaging a cross-disciplinary group of scientists pursuing forefront research on fundamental problems in cosmology. In pursuit of its research goals, it will develop collaborations with other institutions, world-wide. Where appropriate, the Kavli Institute for Cosmological Physics will also foster interactions with other Kavli Institutes.

The creation of the Kavli Institute will bring together cosmological physics at the University of Chicago and will make permanent and expand the existing Center for Cosmological Physics, under the new name of the Kavli Institute for Cosmological Physics. The current name of the Center for Cosmological Physics and its acronym (CFCP) will no longer be used. It is understood that the Kavli endowment will be used to enrich and strengthen the Institute and will not be used as a substitute for federal funding, which will continue to be sought to support the research programs of the Institute.

The research thrusts of The Kavli Institute for Cosmological Physics will encompass the full breadth of the interface between particle physics and astrophysics,

The research thrusts of The Kavli Institute for Cosmological Physics will encompass the full breadth of the interface between particle physics and astrophysics, from string cosmology to ultra-high energy cosmic rays, from inflationary cosmology to dark energy, from cosmic microwave background anisotropy to dark matter detection, and new fields in the future. Some of the initial topics that will be pursued are: elucidating the nature of dark energy and dark matter; testing the inflationary cosmology hypothesis; resolving the mystery of the origin of the highest energy cosmic rays; understanding the role of neutrinos in cosmology; and connecting cosmology with string theory.

11. Grant Acceptance

The pledge and grant are hereby accepted by the University of Chicago, upon and subject to the terms and conditions hereinabove stated.

FOR THE TRUSTEES OF THE UNIVERSITY OF CHICAGO

By: Don M. Randel November 11, 2003
Don M. Randel Date
President

FOR THE KAVLI FOUNDATION

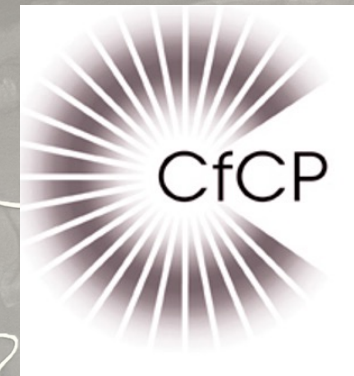
By: David Austin 11/07/03
David Austin Date
President

FOR FRED KAVLI

By: Fred Kavli 11/7/03
Fred Kavli Date



KICP origin, part 2. NSF Physics Frontier Center: Center for Cosmological Physics (2001 – 2019)



CCCP or CCP confusion?



- Dark Energy
- Inflation
- Ultra-high energy particles
- Co-I's
 - John Carlstrom, Sean Carroll, Jim Cronin, Josh Frieman, Wayne Hu, Stephan Meyer, Angela Olinto, Simon Swordy, and Michael Turner
- In 2004, became PFC@KICP
- Bruce Winstein, first KICP Director

Adult-onset
astrophysics, circa 1999



$$\ddot{\phi} + 3H\dot{\phi} + V'(\phi) = 0$$

$$V = \frac{1}{2} m^2 \phi^2$$



homogeneous
 isn't a parameter) SG

for $\phi_i = 2$ $\ln \tau = 1$ $G = 1/m^2$

2 x solⁿ for $\phi_i = 1$ SG

$H_0 = 10^{-33} e$

$H^2 = \frac{8\pi V}{3} / m_{pl}^2$

Guiding principle for ERC design: Cadillac labs, Yugo offices, and great interaction spaces (2010 -2015)



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homogeneous
isn't a par
for $\phi_i =$
 $2 \times \text{sol}^n$ for
= 0

$\frac{1}{2} m^2 \phi^2$
 $m^2 \phi$
 $\frac{d}{d\tau} =$
 $\frac{d}{dt} = H_0 \frac{d}{d\tau}$
 $\sqrt{z} \phi = 0$
 $H = H_0 (1 +$
 $\phi = 0$
 $= H_0 \hat{\tau}$
approx



ERC 2014



TAAC June 2012

$$L + 3H\phi + V'(\phi) = 0$$

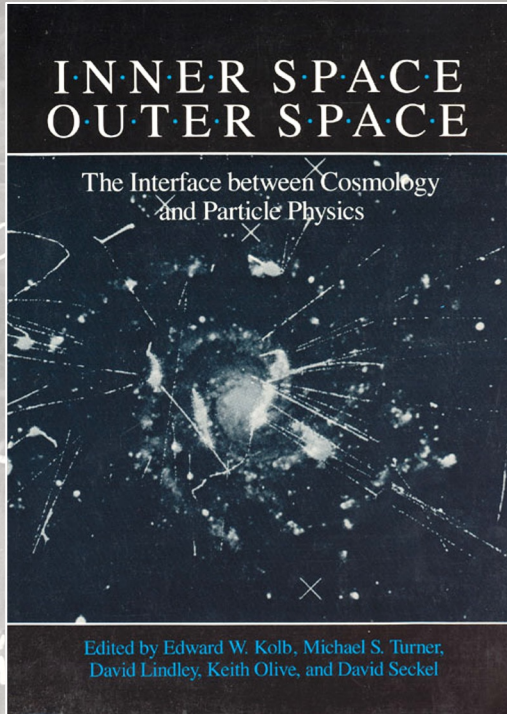
$$H = \frac{8\pi V}{3} \frac{1}{\text{mpl}}^2$$

initial values: $\phi = 0$

$$= H_0 \hat{\tau}$$

approx

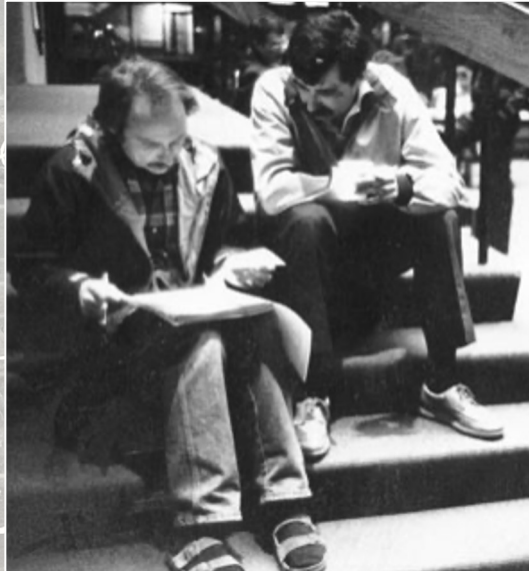
KICP origins, part 3. Fermilab (NASA) Astrophysics (1983 – today)



The study of
The Very large (Cosmology)
and
The Very Small (Elementary Particles)
IS
COMING TOGETHER



1981 hike in the Dolomites



MICHAEL TURNER
CO-CHAIRMAN

INNER SPACE/OUTER SPACE

THE OFFICIAL CONFERENCE OF
THE 1984 SUMMER OLYMPICS

$V'(\phi) = 0$
 τ^2
 $\tau = \frac{1}{H_0}$
 $\frac{d}{dt} = H_0 \frac{d}{d\tau}$
 $= 0$
 $H = H_0 (1 + \dots)$
 $= H_0 \hat{\tau}$
[approx]

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$V'(\phi) = 0$
 ϕ^2
 $T = \dots$
 $G = \dots$
 $\frac{d}{dt} = H_0 \frac{d}{d\tau}$
 $b = 0$
 $H = H_0 (1 + \dots)$
 $= H_0 \tau$
 τ_{app}

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$+ V'(\phi) = 0$

$2 \phi^2$

2ψ

$\frac{d}{dt} =$

$\frac{d}{dt} = H_0 \frac{d}{dt}$

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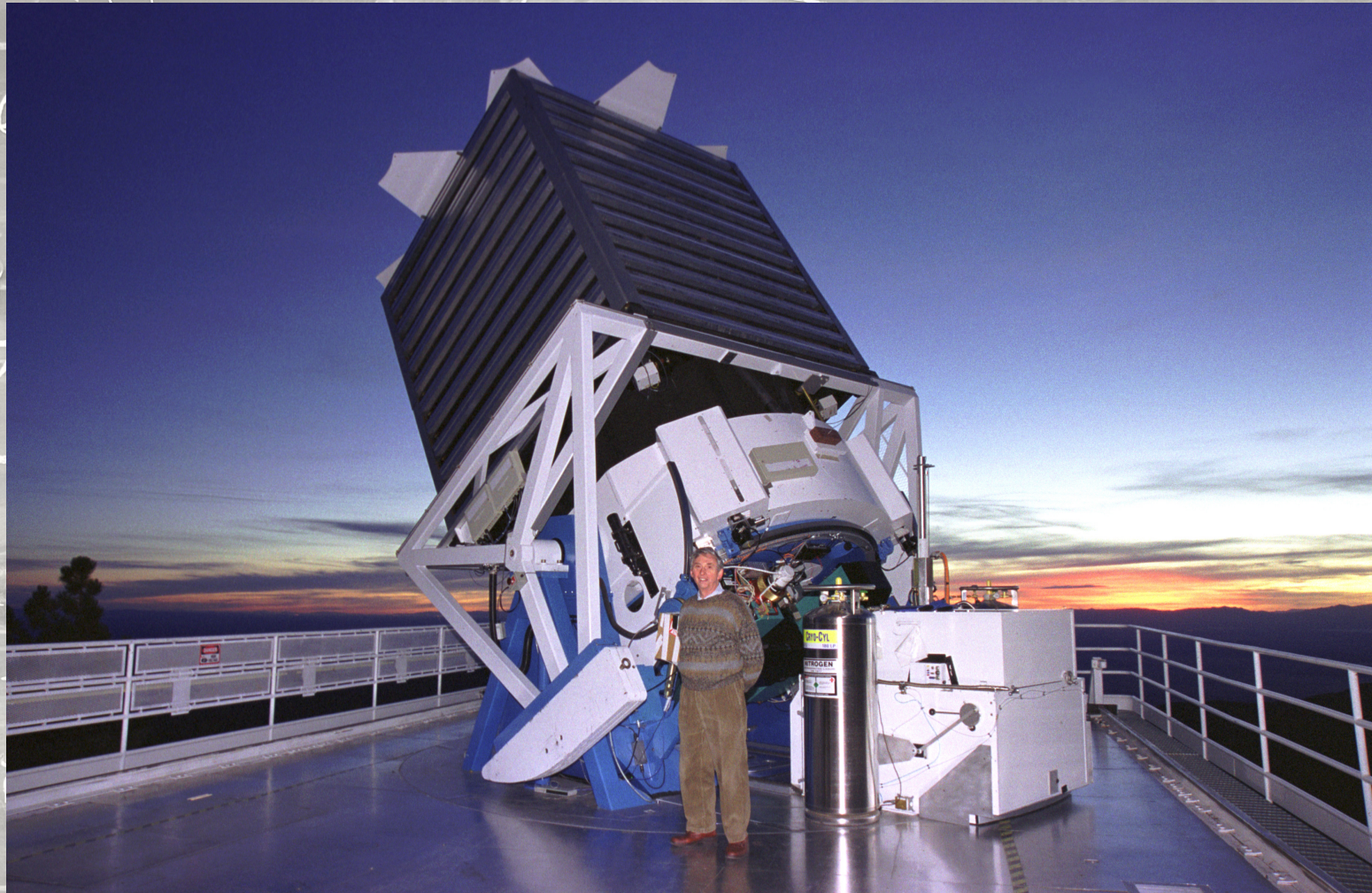
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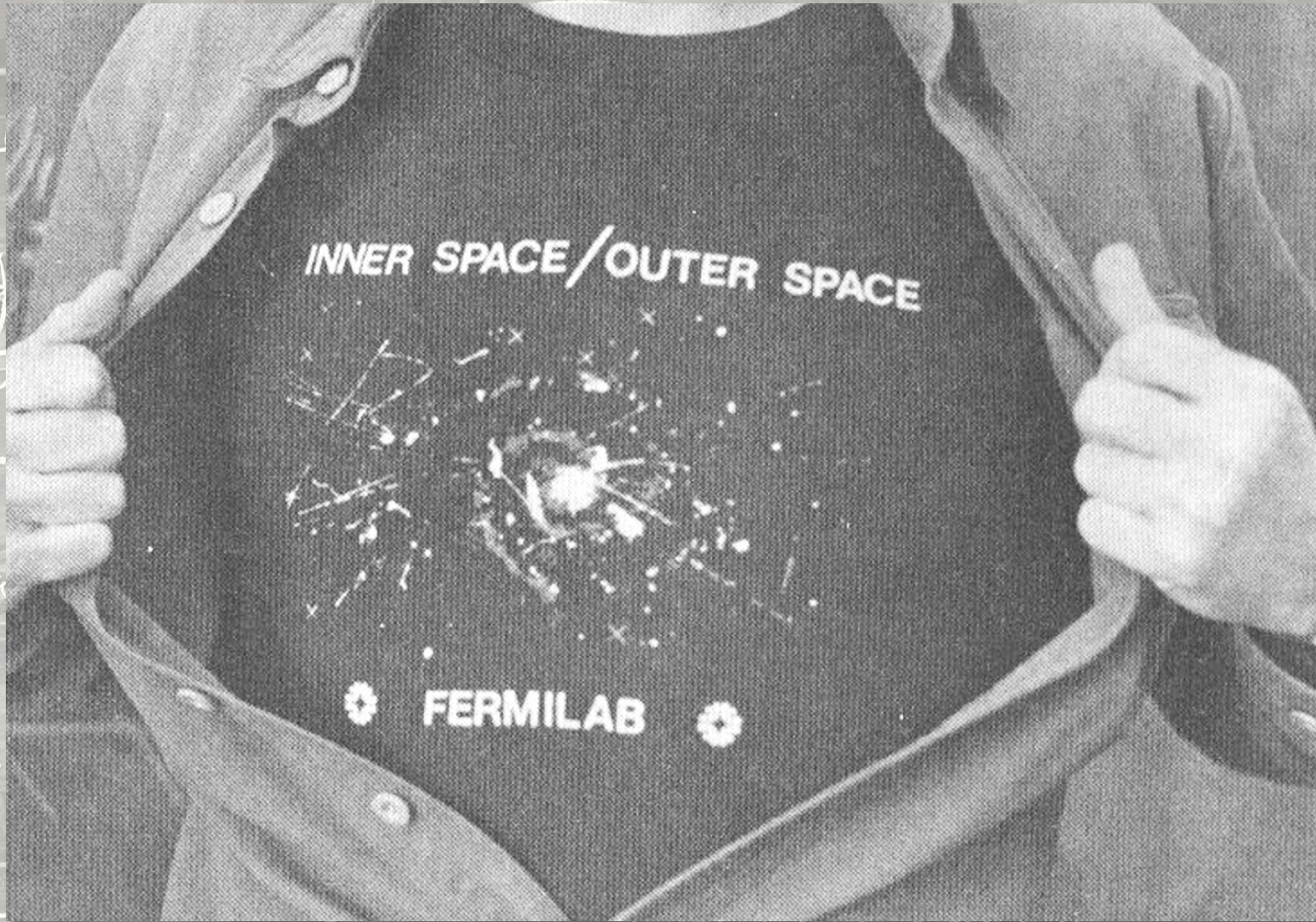
The SDSS and the birth of survey science



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$\sqrt{(\phi)} = 0$
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 $m^2 \phi$
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 $\frac{d}{dt} = H_0 \frac{d}{dt}$
 $\phi = 0$
 $H = H_0 (1 +$
 $= H_0 \hat{t}$
initial values:
approx

The birth of the conference T shirt



$\sim 10^{12} G$
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$+ V'(\phi) = 0$
 $m^2 \phi^2$
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 $\frac{d}{d\tau} =$
 $\frac{d}{dt} = H_0 \frac{d}{d\tau}$
 $\phi = 0$
 $H = H_0 (1 +$
 $= H_0 \hat{\tau}$
approx

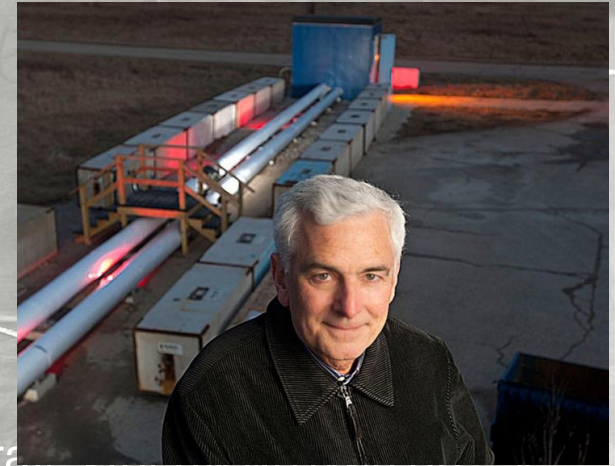
Workshops: The wormshop, ...



May day, 1985



The Fermilab Particle Astrophysics Center



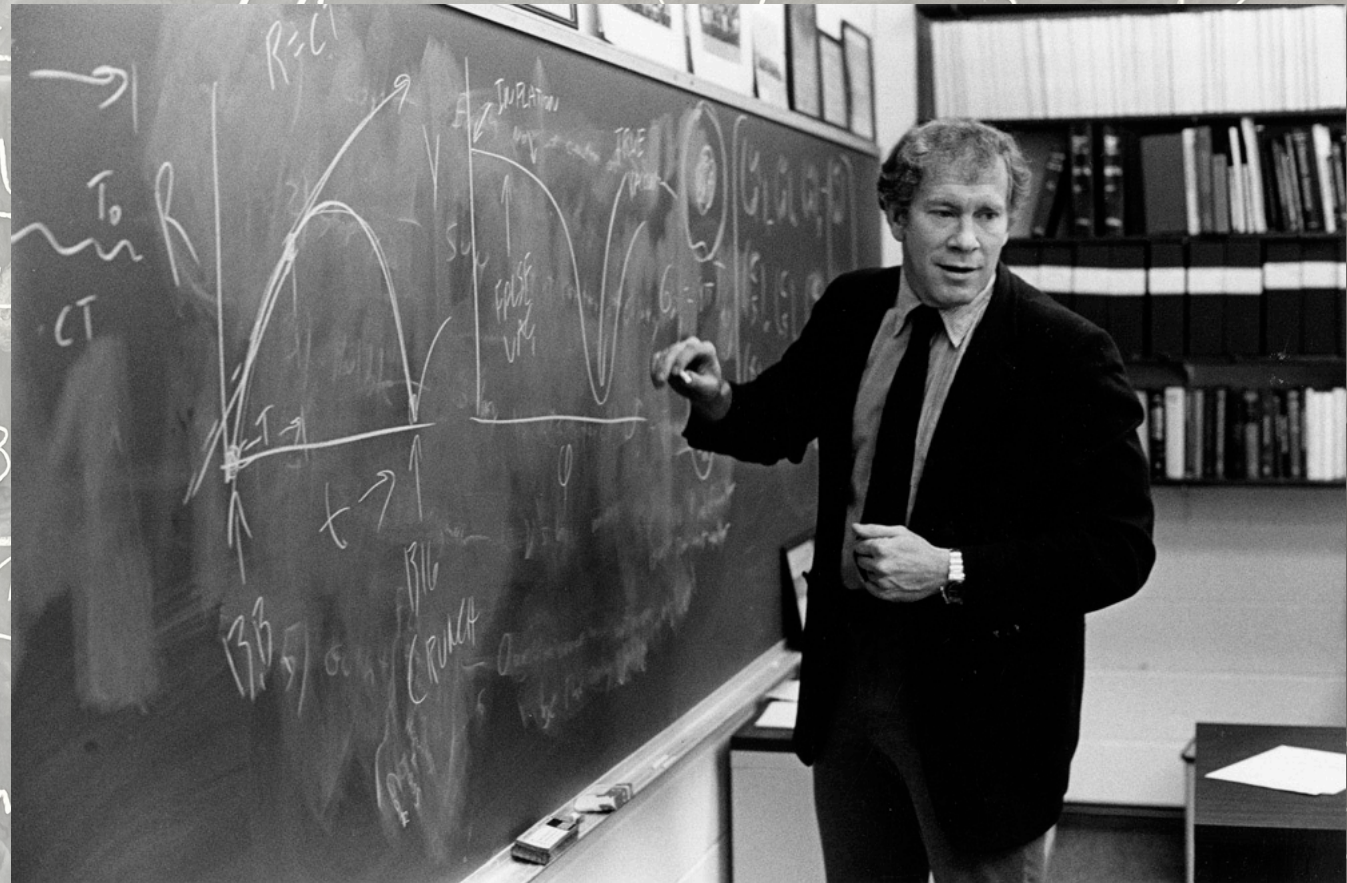
1st Director 2008



$$H^2 = \frac{8\pi V}{3} / m_{pl}^2$$

KICP origins, part 4. David Schramm revitalizes Department of Astronomy & Astrophysics and brings cosmology to UChicago, 1978 – 1984

- 1978: Richard Kron
- 1980: Michael Turner
 - 2022 Josh Frieman
- 1986: Rocky Kolb
- 1993: Stephan Meyer
- 1996: Angela Olinto
- 1997: John Carlstrom
- [1999: Sean Carroll
- 2000: Wayne Hu
- 2001: Andrey Kravtsov]



Origins, part 4: UChicago invents interdisciplinary research: Fermi and Franck Institutes (1946 –)



Called the "finest example of neo-Stalinist architecture"

The greatest hits (that I can remember)

- Our alums: students and postdocs (on the program and many, many more)
- The diverse (early/late career; physicist/astronomer; theorist/experimentalist/observer), interdisciplinary, and supportive research community
- Cosmic microwave background
 - DASI, SPTxx, WMAP, QUIET, CAPMAP, CMB-S4, ... , Simons Observatory
 - Discovery of CMB polarization, lensed B-modes, SZ and SZ discovered clusters
 - BICEP/KECK
- Dark Energy Survey
 - New dwarf galaxies and all the science!
- Dark Matter detectors
 - PICO, DAMIC, Xenon, ...
- Pierre Auger Observatory
- Coherent neutrino scattering
- Gravitational waves and gravitational-wave astrophysics
- RNO-G (phased-array neutrino detection)
- Innovative and impactful Education and Outreach, including Alan Alda training
- Theory that inspires, guides the design of experiments and gets the most out of the data



$$k + 3 \perp \phi + V'(\phi) = 0$$
$$m^2 \phi^2 / \hbar =$$



The greatest hits (the first 10 years)



Kavli Institute
For Cosmological Physics
At The University of Chicago

Happy 10th Birthday!
2004 2014



Inner Space Outer Space
Texas in Chicago: 20th Texas Symposium on Relativistic Astrophysics
Inner Space/Outer Space II
The Pritzker Symposium on the Status of Inflationary Cosmology
Short Course: "The New Cosmology: From Quantum Fluctuations to the Accelerating Universe"
Cosmological Probes of Dark Energy (1st CICP workshop)
COSMO-02
Pierre Auger event reconstruction
Cosmology with Supernovae
Zwicky Cluster Surveys
The Future of Dark Matter Detection
Symposium in honor of David Spergel
New Views of the Universe
Defining the Problem and Taking Action
Visualization of Astrophysical Data: Art and Education
"Entropy and the Arrow of Time"
Cosmic Cartography: Mapping the Universe from the Big Bang to the Present
The Sloan Digital Sky Survey: Viewing the Universe via the World Wide Web
The Path to CMBPol - Upcoming Measurements of CMB Polarization
Exploring the Universe Bit by Bit
10th Great Lakes Cosmology Workshop
Short Course: "The Dark Universe"
Yerkes Summer Institute: Detectors, Super-Sensing
The 4th Yearning
Identification of Dark Matter 2012
Hands-On Summer School: Dark Matter Detectors
Galaxies within the Cosmic Web
Communicating Science with Alan Alda
High-Energy Messengers
Connecting the Non-Thermal Extragalactic Background
Hands-On Summer School: Teaching the Next Generation of Teachers-Scholars
COSMO 2014

BBN Evidence for Particle Dark Matter
Quantum Fluctuations during Inflation seed large scale structure:
Birth of CDM
Formation of the NASA/Fermilab Theoretical Astrophysics Group
The Early Universe published
COBE Detection of CMB anisotropy
Center for Astrophysical Research in Atlanta established
Shawn Digital Sky Survey: First Light
SDSS discovers $z > 6$ QSOs
PFIC: Center for Cosmological Physics created as an NSF PFC
Eric Winstein PI
TOPHA Launched
CEASV Launched
DASI Observes CMB Anisotropy Peaks
NSF funds the South Pole Telescope
IAWMAP Results
Pierre Auger Observatory begins collecting data
Kavli Foundation endows KICP
Creation of Fermilab Center for Particle Astrophysics
CHEA Billions Bright
SDSS-1 & SDSS Supernova Survey
KICP/ANU Director Initiative
PFIC2: Stephen Taylor, PI and John Carlstrom, KICP Director
South Pole Telescope: First Light
Pierre Auger Observatory: Concentration of High-Energy Cosmic Rays with Nearby Extragalactic Objects
Final CAPMAP results
First COUPP results
SPT discovers galaxy clusters by QUET
QUET Deployed
QUAD Polarization Results
First CoGeNT result
PFIC3: Michael Turner, PI and KICP Director
VERITAS discovers first 100 GeV photons coming from the Crab Nebula
Cosmic Frontier Group: breaks ground
SPT finishes 2500 sq deg SZ survey
SPTol first light
Dark Energy Survey First Light
First Bubble for COUPP-60
KICP joins the DarkSide experiment
SPT detects B-mode P polarization
Large Scale DMVC Ruled
Fermilab Hallometer

1980s
1990s
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014



The best is still ahead: predictions for the next 20 years

- Answer one of LCDM's questions
 - Dark Matter particle, Inflation B-modes, or clue about dark energy
- Significant modification of LCDM
 - Early dark energy, quintessence, primordial black holes
- GZK neutrinos detected
- Powerful new cosmological probe invented
- Theoretical advance as important as BAO, B-modes, ...
 - Worthy alternative to inflation
 - Testable, fundamental inflation model
 - Compelling dark matter candidate
- Big surprise at the boundaries of particle physics and cosmology

Resolution of the H_0 discrepancy? Theory beyond Cold Dark Matter? Explanation of Cosmic Acceleration? Transformation of Inflation into a fundamental theory? Multiverse or not? Dark Matter particle or not? More for cosmology to learn from particle physics? Critical tools for making progress?

Cosmic Controversies

Is cosmology on the verge of a fundamental description of the Universe based upon Λ CDM, or on the cusp of a major disruption?

KICP

Kavli Institute
For Cosmological Physics
At The University of Chicago

October 5–8 2019 Chicago IL
Gleacher Center at the University of Chicago
8 distinguished panels, plenary sessions and posters
kicp.uchicago.edu/cosmocon

Final thoughts

- First twenty fantastic years exceeded all expectations!
- Precision cosmology is hard; accurate cosmology is even harder!
- World-leading institutions must change; change can be chaotic, difficult and risky
 - Be fearless and bold with eye on the North Star
 - Important and timely often attracts the best and the brightest young scientists
- It is all about the people and the interactions! Get that right and the rest will follow.
- KICP has two wonderful partners: Kavli Foundation and UChicago
- Cosmology has changed (now industrial class science)
 - Idea driven \rightarrow data-driven (not forever)
 - Be careful what you wish for: theorists who begged for more data and are now survey scientists and data scientists
- The very best research involves taking risks, commitment, making mistakes, and being confused. You need a supportive community and environment and KICP@UChicago is just that.

The Early Universe



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