Title: The Connected Universe: Relating Early, Intermediate and Late Universe with cosmological data

Speakers: Vivian Miranda

Series: Cosmology & Gravitation

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Abstract: The standard model of cosmology is built upon on a series of propositions on how the early, intermediate, and late epochs of the Universe behave. In particular, it predicts that dark energy and dark matter currently pervades the cosmos. Understanding the properties of the dark sector is plausibly the biggest challenge in theoretical physics. There is, however, a broad assumption in cosmology that the Universe on its earlier stages is fully understood and that discrepancies between the standard model of cosmology and current data are suggestive of distinct dark energy properties. Uncertainties on the validity of this hypothesis are not usually taken into account when forecasting survey capabilities, even though our investigations might be obfuscated if the intermediate and early Universe did behave abnormally. In this colloquium, I propose a program to investigate dark energy and earlier aspects of our Universe simultaneously, through space missions in the 2020s in combination with ground-based observatories. This program will help guide the strategy for the future LSST and WFIRST supernovae and weak lensing surveys. My investigations on how properties of the early and intermediate Universe affect inferences on dark energy (and vice-versa) will also support community understanding of how future missions can be employed to test some of the core hypotheses of the standard model of cosmology.

The connected universe

Relating Early, Intermediate and Late Universe with cosmological data

Vivian Miranda

Senior Postdoctoral Research Associate - University of Arizona

Pipeline Scientist LSST-DESC Collaboration (Rubin Observatory)

Member of Dark Energy Survey Collaboration

Member of the LSST-DESC Collaboration

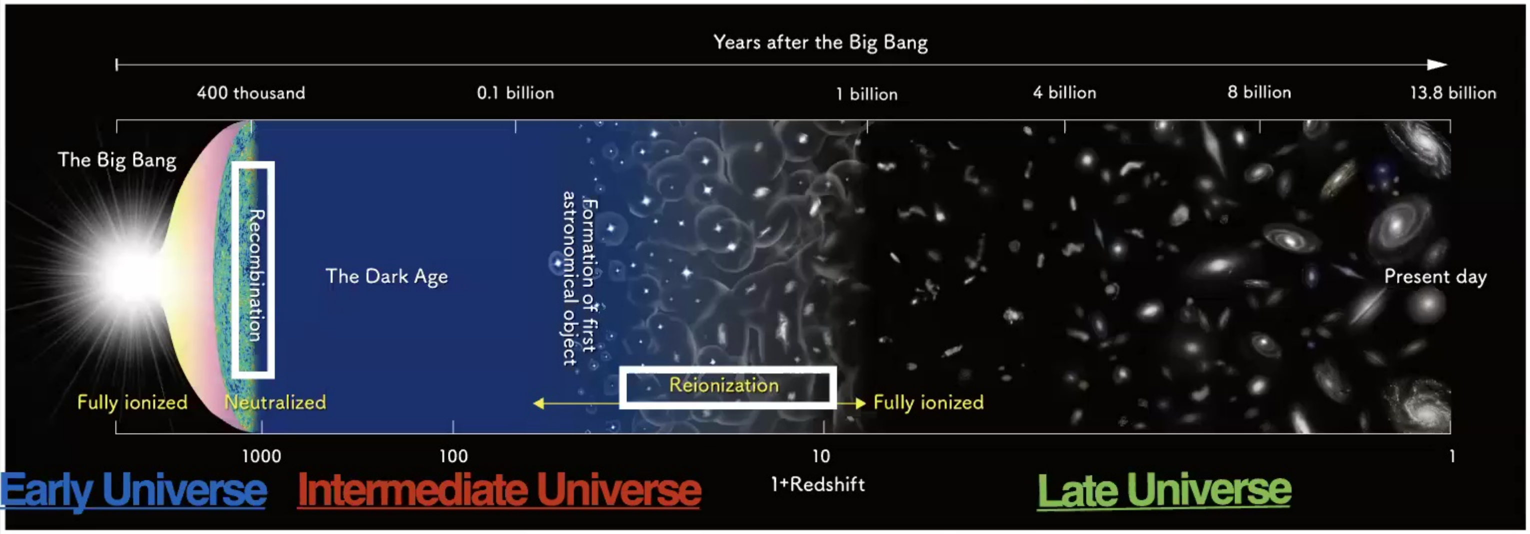
Co-I of the Supernova Science group at Rubin (WFIRST)

Member of the High Latitude Survey Rubin (WFIRST) group

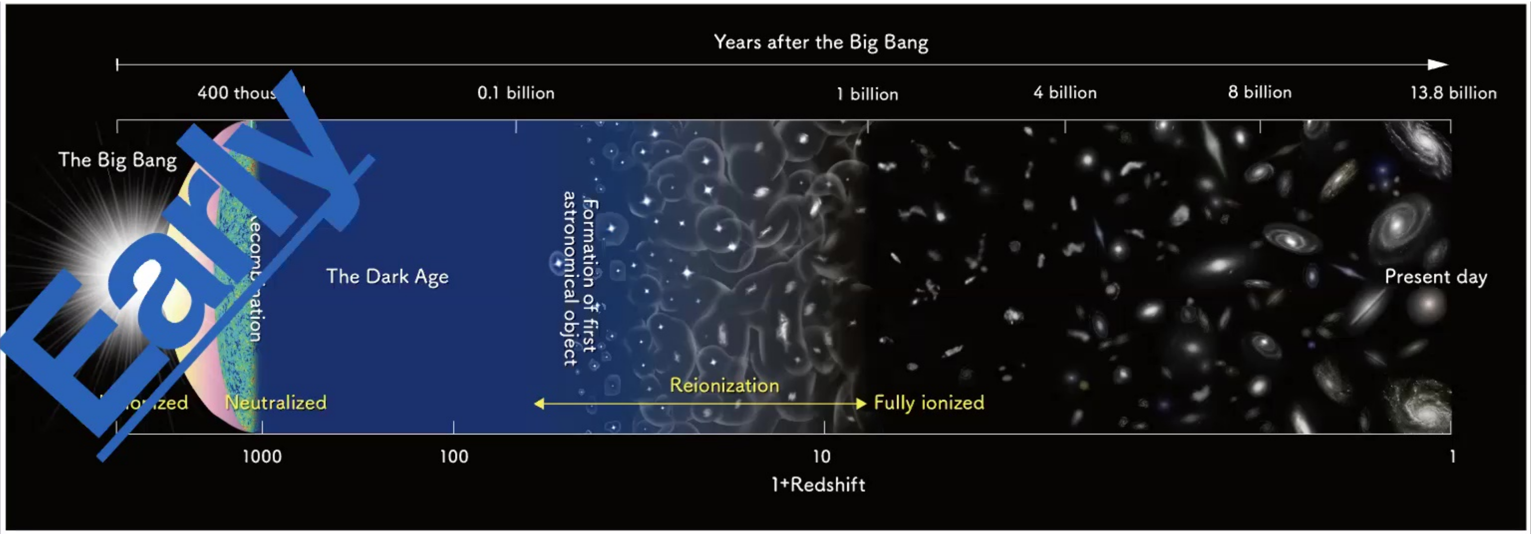
Big Picture: Late Epoch affected by the all history of the cosmos

Our Universe has a rich history with complex dynamics.

Break the Universe's history into three epochs: Early, Intermediate, Late



These 3 epochs affect the current expansion and structure formation

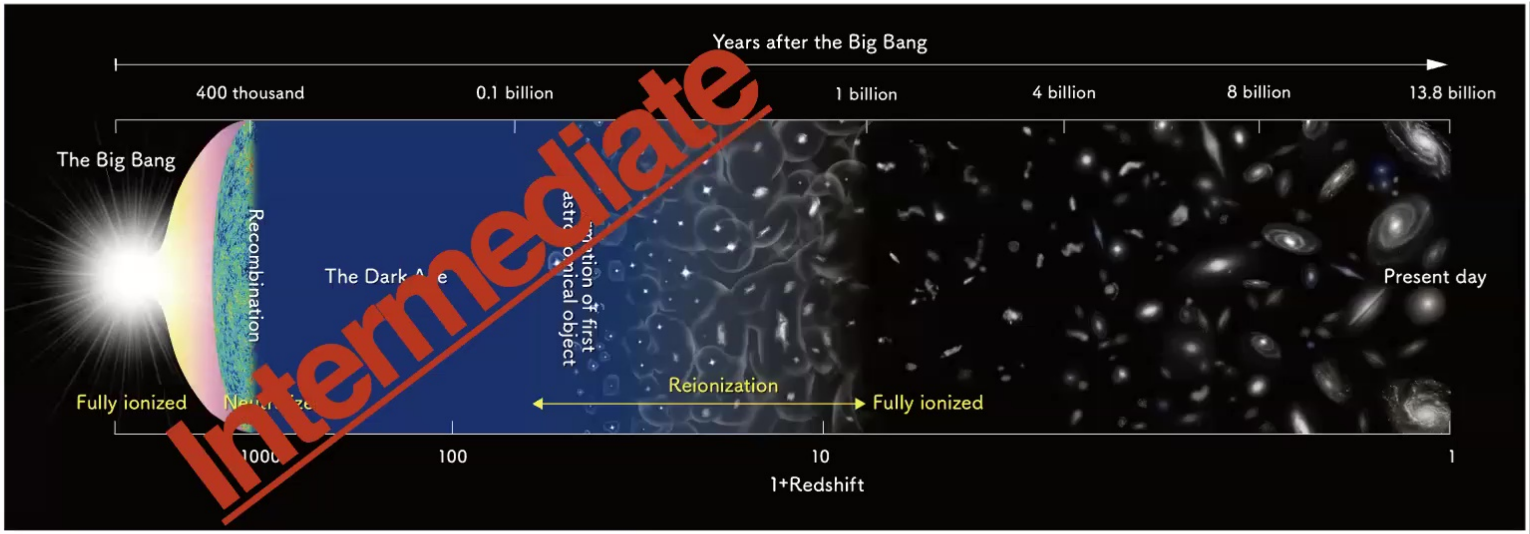


<u>Inflation</u> - first phase of accelerated expansion. **<u>Not</u>** Cosmological Constant

<u>Radiation Era</u> - expansion too fast for structures to grow.

<u>Recombination/CMB</u> - universe became transparent; Cosmic Microwave Background was emitted.

<u>Golden era</u> for the Cosmic Microwave Background

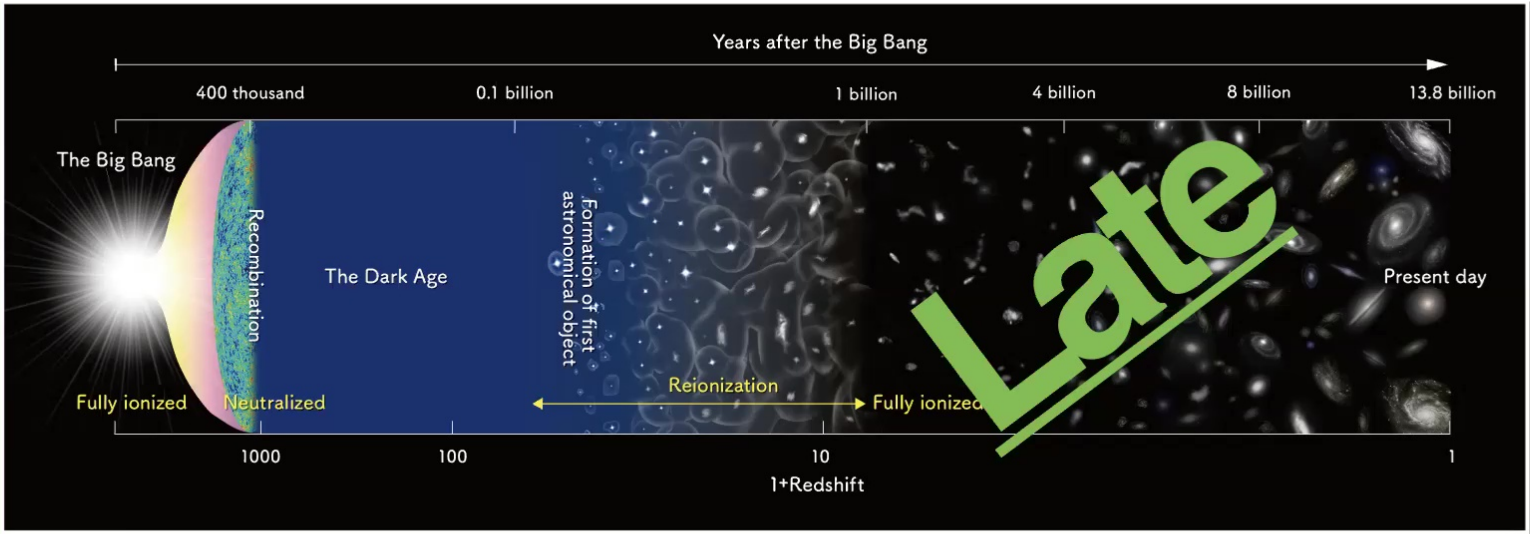


Cold Dark Matter - expansion rate gentle enough for structures to grow.

Massive Neutrinos: became non-relativistic.

Reionization: universe ionized again and became slightly opaque.
Affected the photons of the Cosmic Microwave Background

Golden era for 21-cm experiments



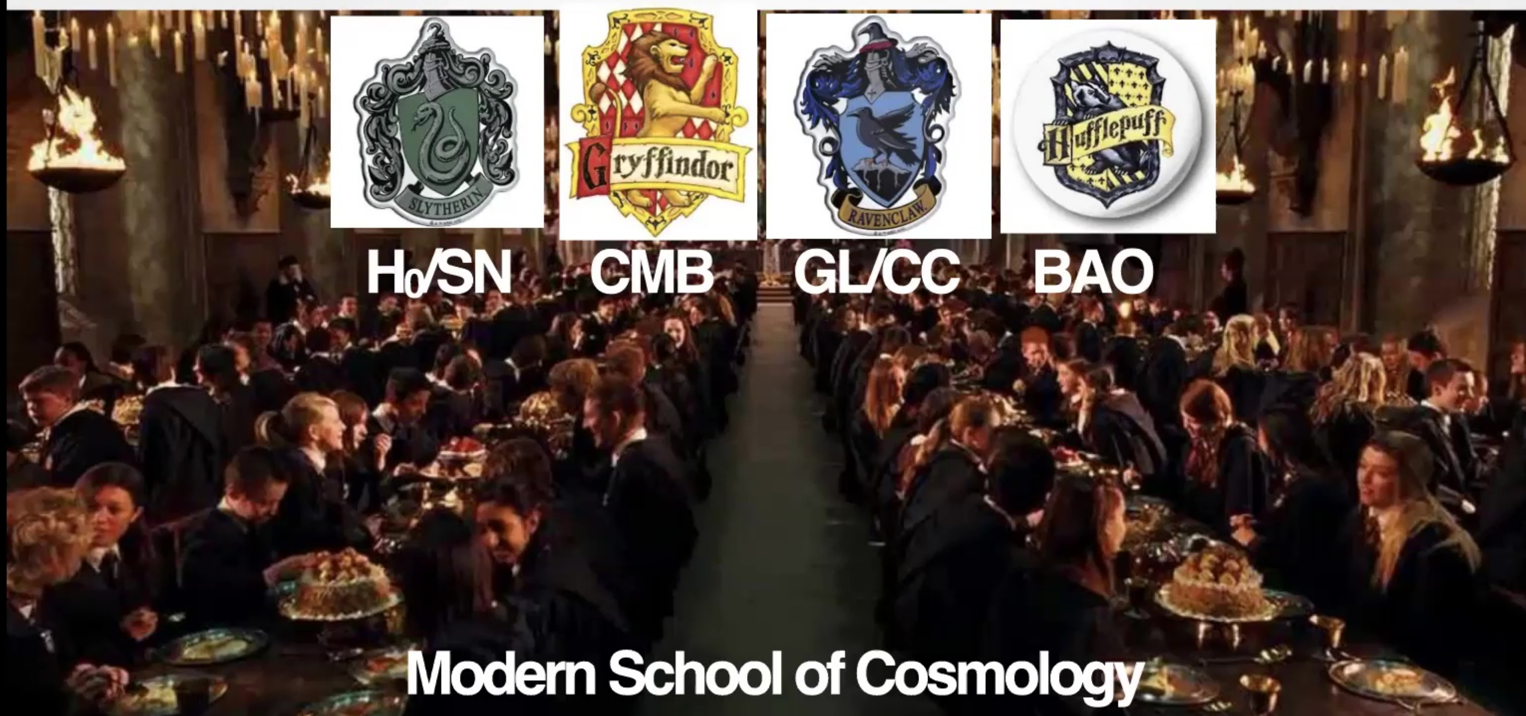
Acceleration - universe accelerates again (~ second half of Late epoch).
Maybe Cosmological Constant.

Non-Linear Evolution - structure formation became highly non-linear.
Peak of Star Formation and other baryonic effects

Plethora of Probes - that measures geometry and structure formation.

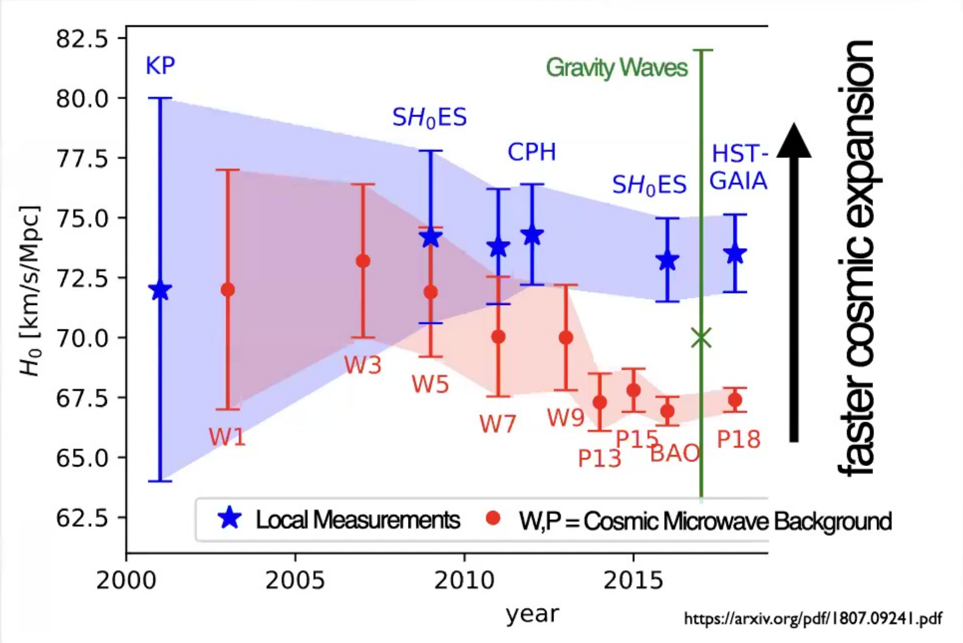
Golden Era for optical astronomy.

To probe all epochs, there are houses of observers



Peace between schools is fragile. Tension rises in the air

Cosmic Microwave Background disagrees with local measurements of the Hubble Constant. Disagreement is rising as we gather more data.



H_0 = Local Rate of Cosmic Expansion

Local Universe is expanding too fast!

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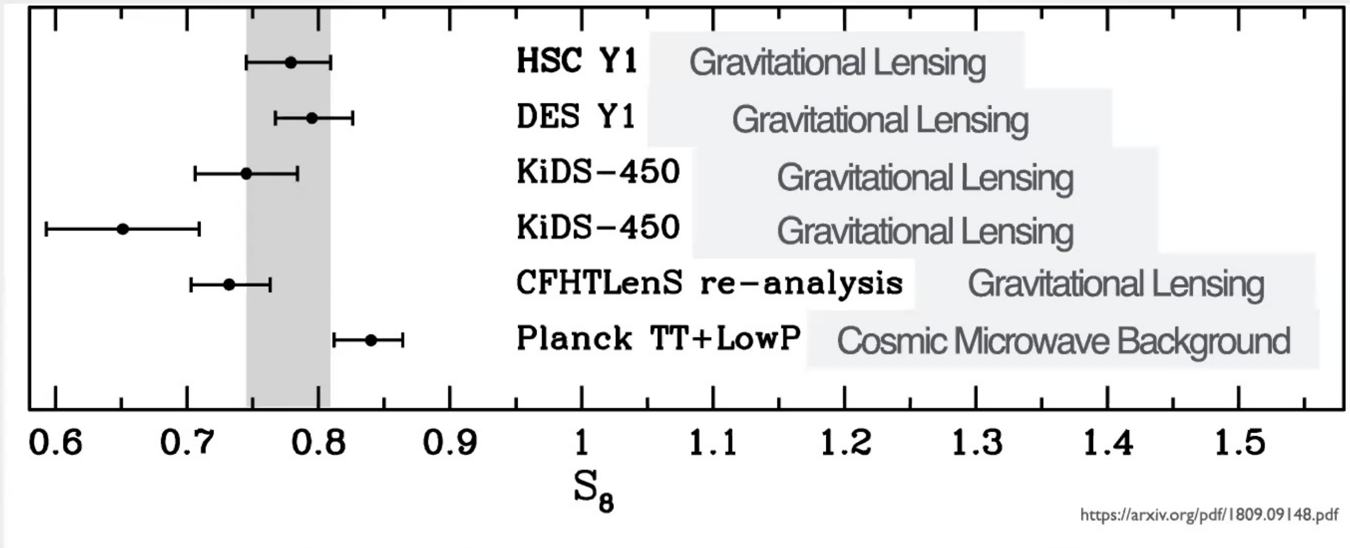
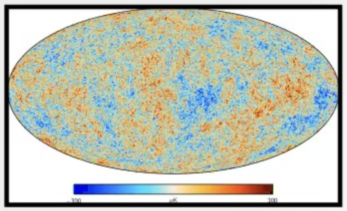
Peace between schools is fragile. Tension rises in the air



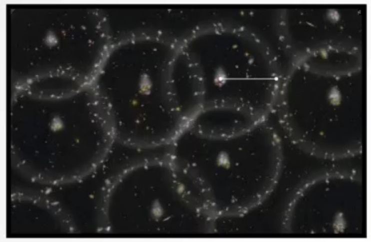
Fixed Amount Dark Matter: larger S_8 => universe more inhomogeneous

Fixed inhomogeneity: larger S_8 => more dark matter in the universe

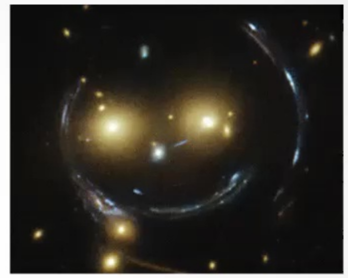
Peace between schools is fragile. Tension rises in the air



CMB



BAO



GL

H_0/SN

If this Universe is the Standard Model of Cosmology

This Universe expands too fast, and it is either too homogeneous or has too little dark matter.

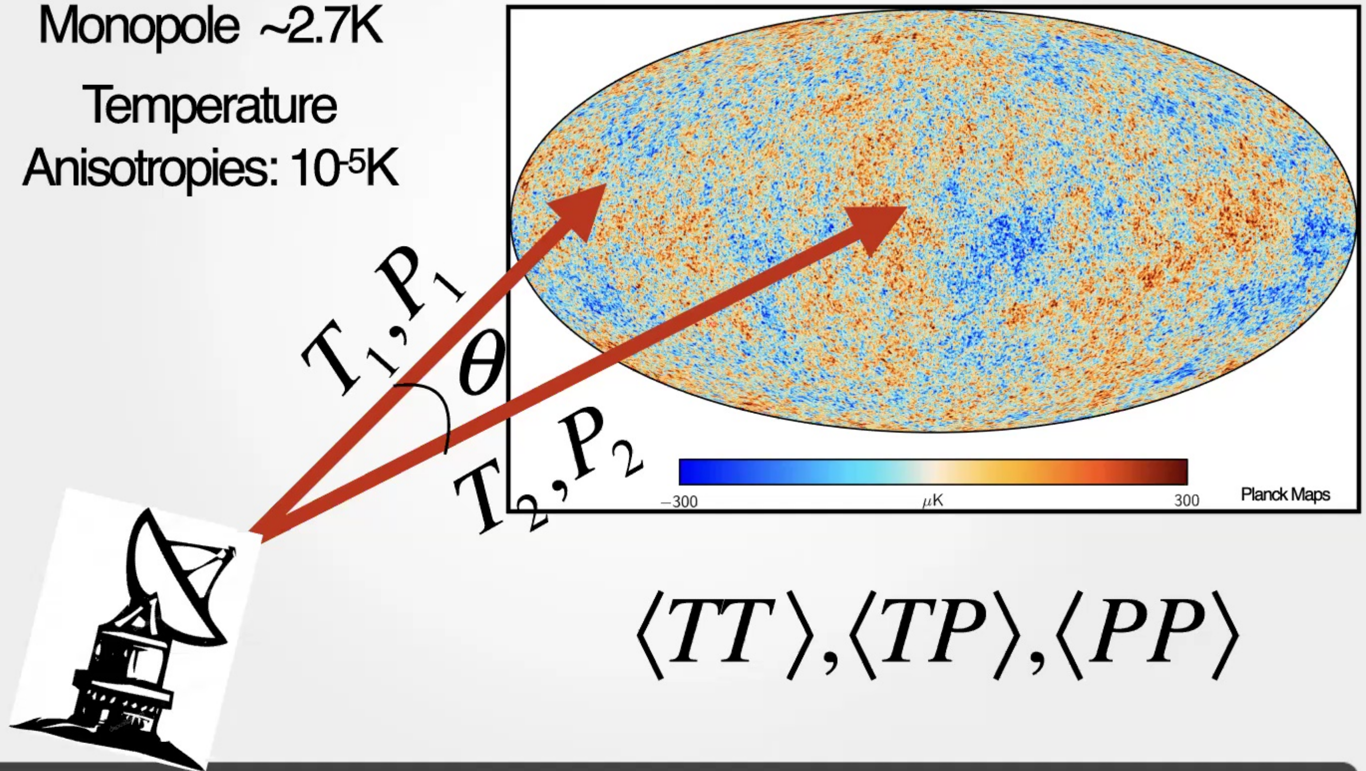
Such results may imply Dark Energy is not the Cosmological Constant

Brief Introduction on two-point Correlation Functions and Power Spectra

Two-point correlation function - Cosmic Microwave Background

Monopole ~2.7K

Temperature Anisotropies: 10^{-5}K



$$\langle TT \rangle, \langle TP \rangle, \langle PP \rangle$$

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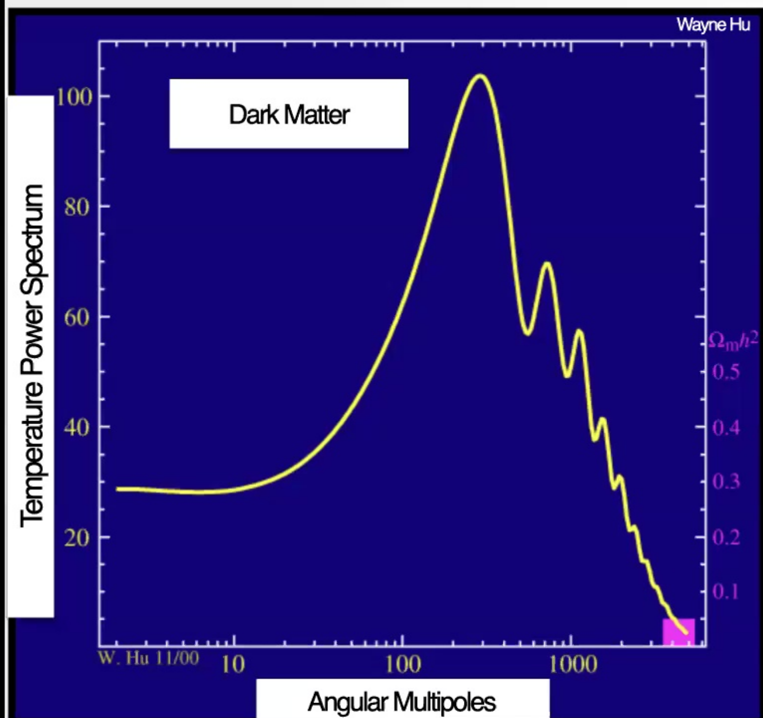
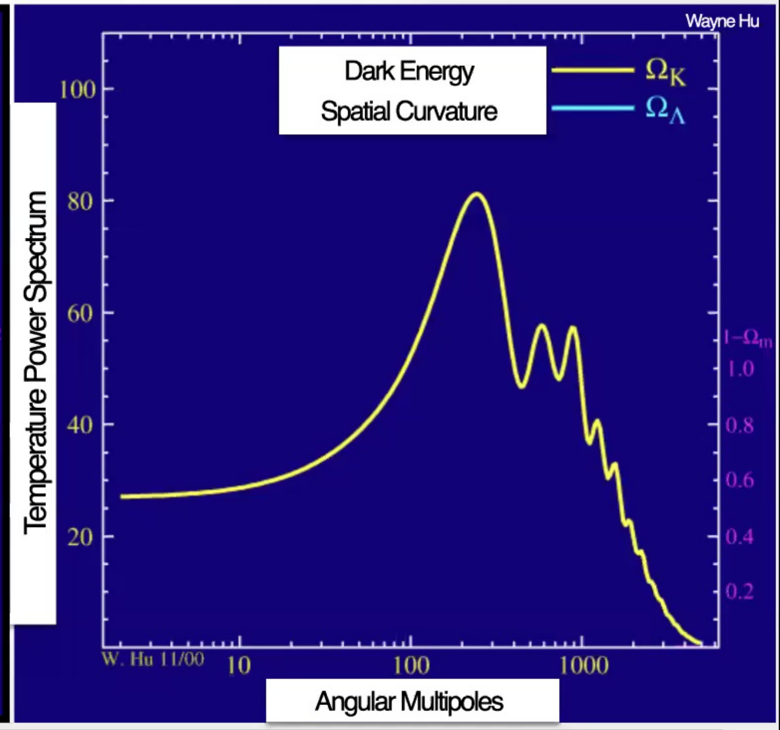
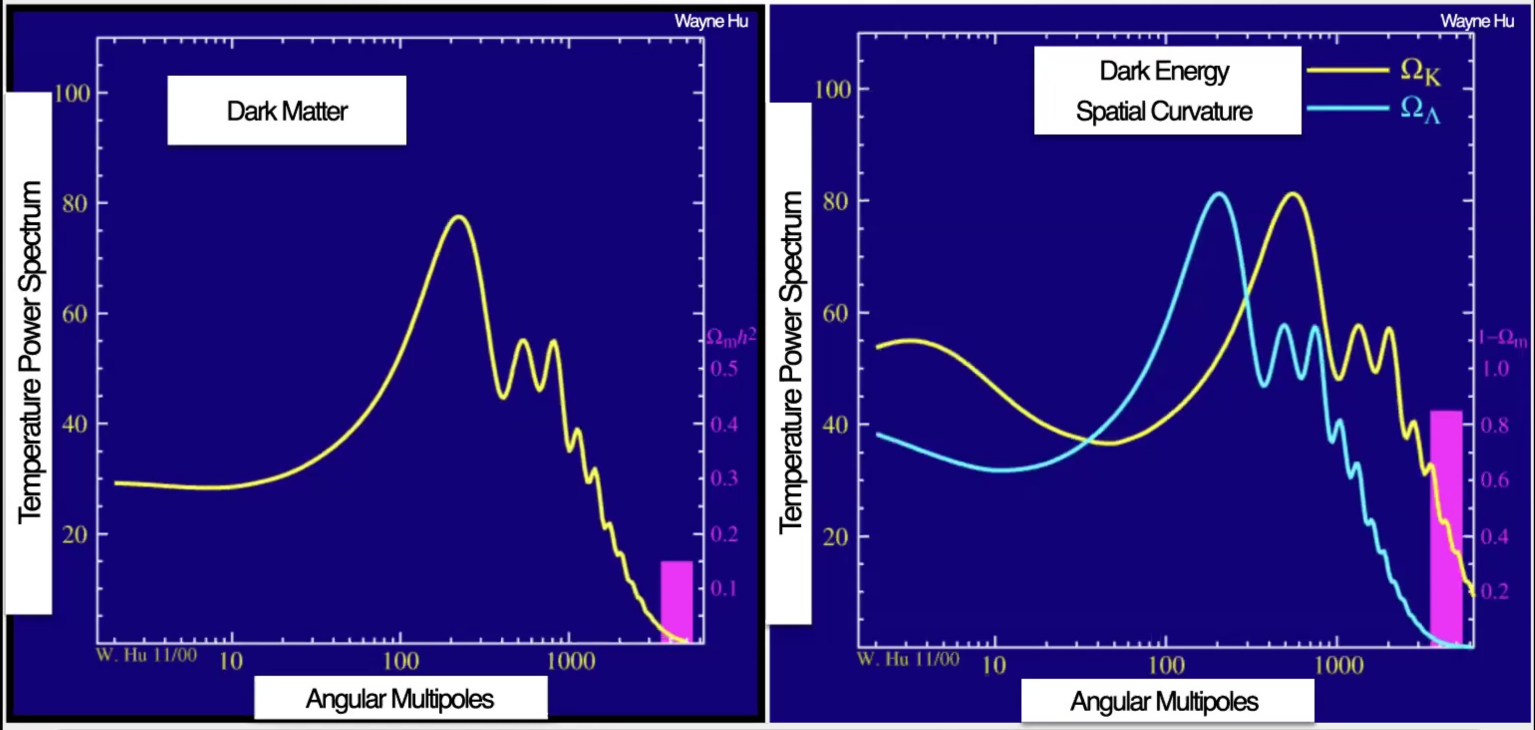
Fourier Transform: Power Spectrum - Cosmic Microwave Background



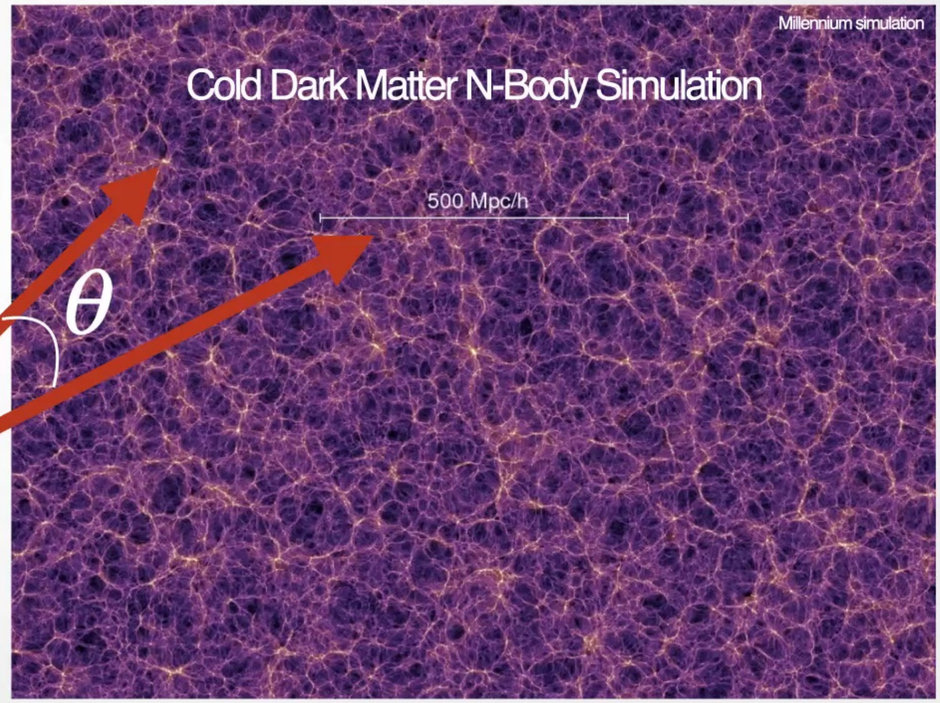


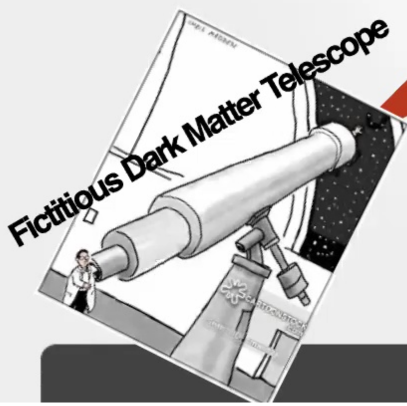
Fourier Transform: Power Spectrum - Cosmic Microwave Background



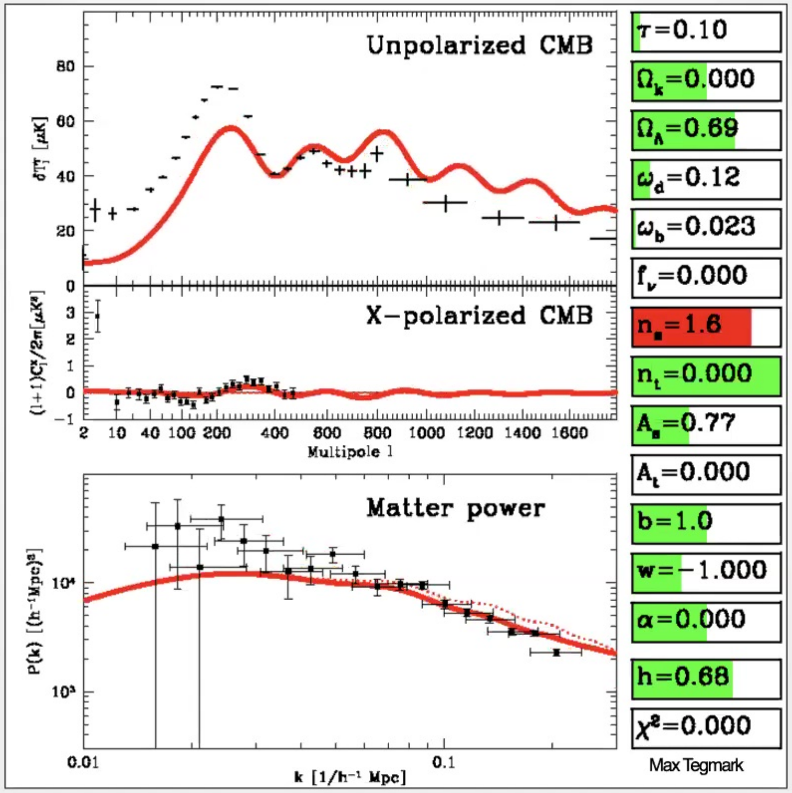
Two-point correlation function - Dark Matter

Dark Matter two-point correlation function





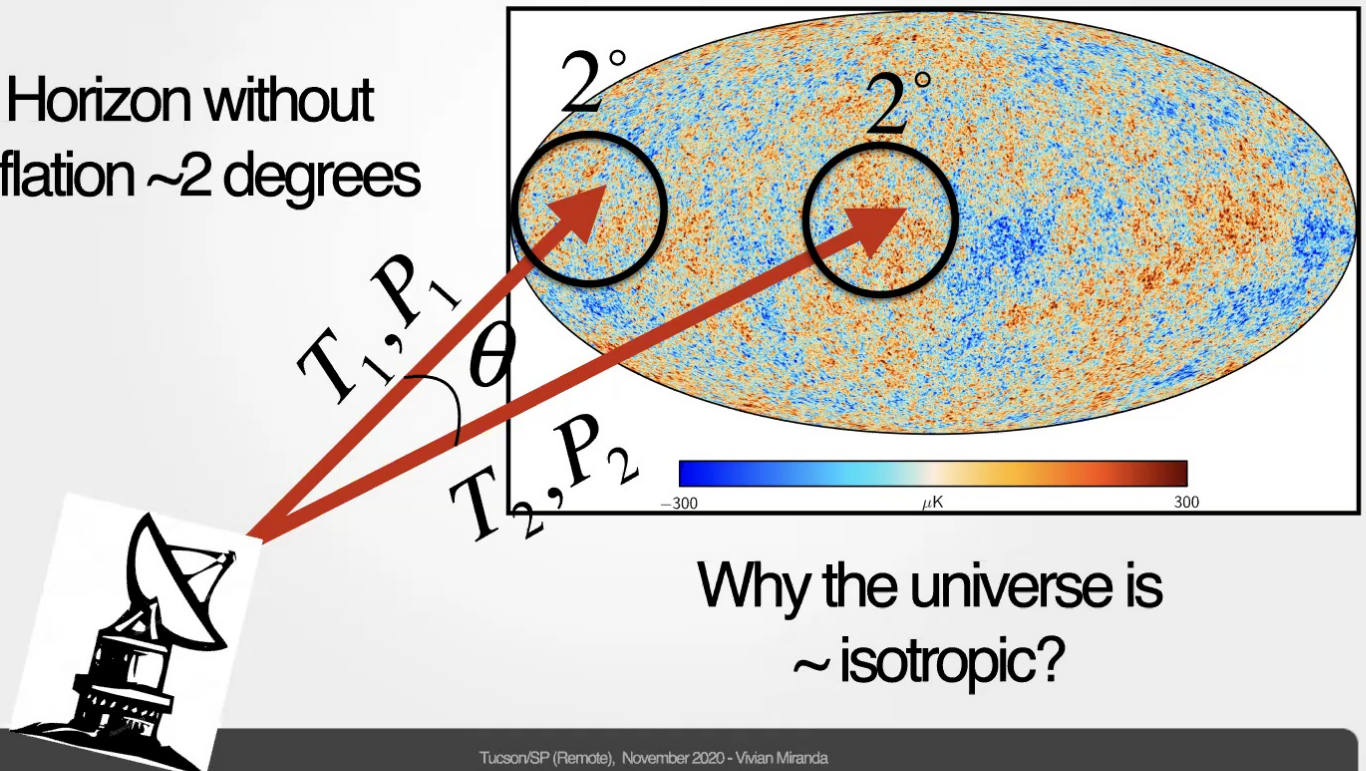
Fourier Transform: Power Spectrum - Dark Matter



Early Universe

Why do we need inflation?

Horizon without inflation ~2 degrees



Why the universe is ~ isotropic?

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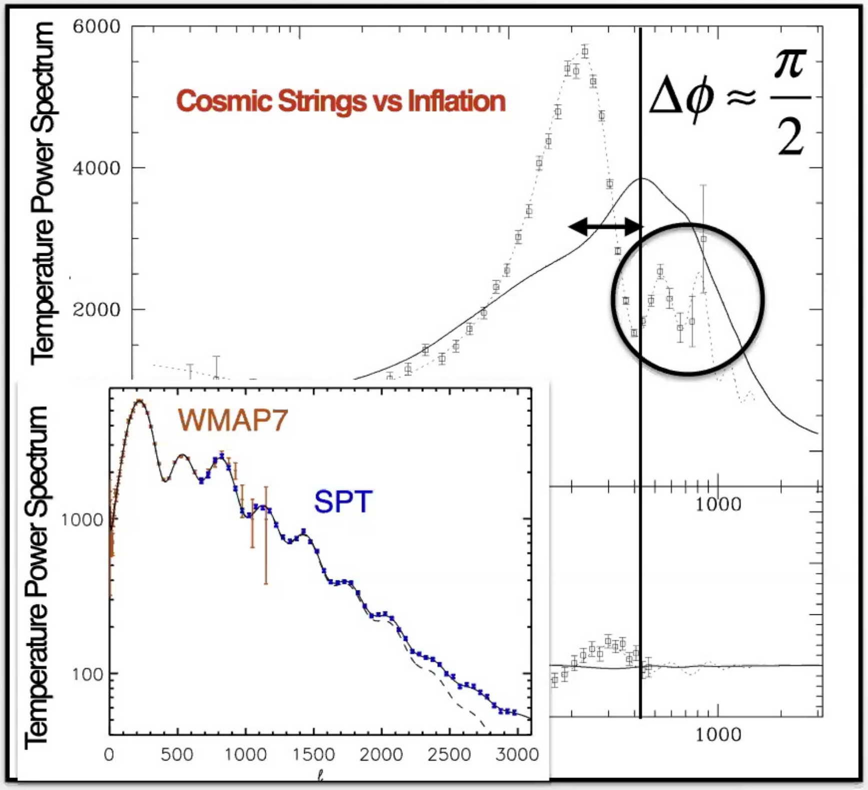
Why do we need inflation?



The CMB second/third.. peaks exist!

Perturbations are adiabatic and coherent

https://arxiv.org/abs/1210.7231

https://arxiv.org/abs/astro-ph/0503364

https://arxiv.org/abs/1109.4947

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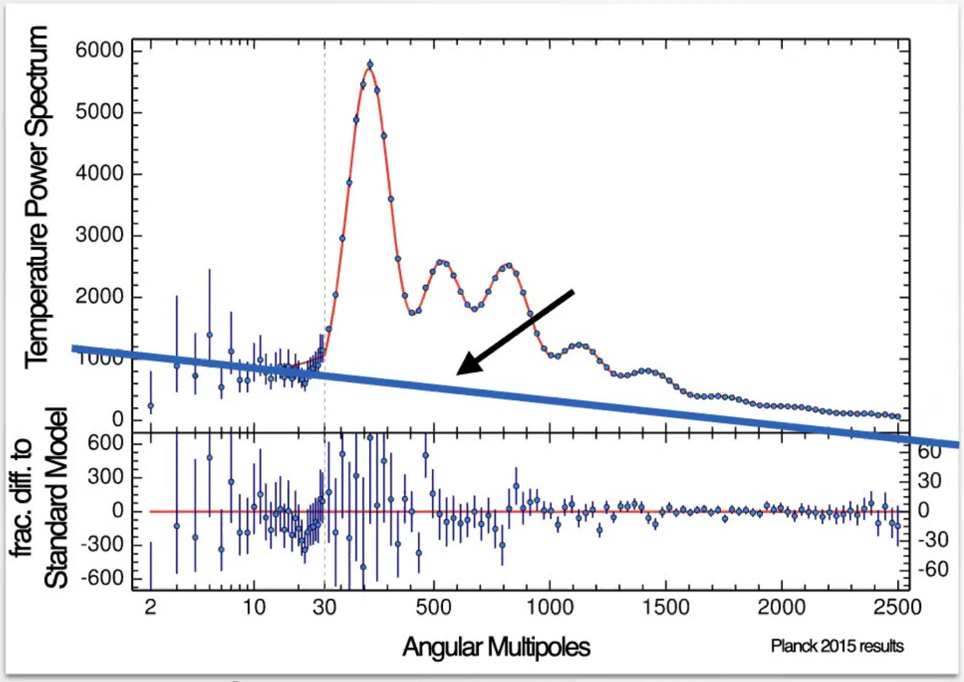
Temperature Power Spectrum: Basic Cookbook



Inflationary seeds

$$A_s \left(\frac{k}{k_0} \right)^{n_s - 1}$$

tilt

Amplitude

$$\langle TT \rangle \propto \int d \ln k \text{ Inflation} \times \text{Transfer}$$

Fourier Transform = Power Law

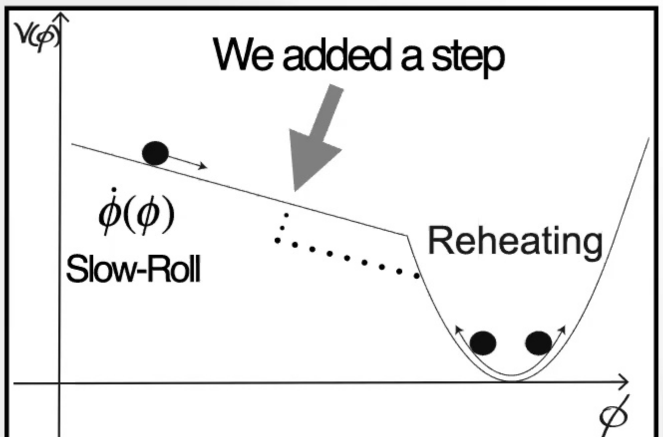
Examples of Inflation that violate the basic picture

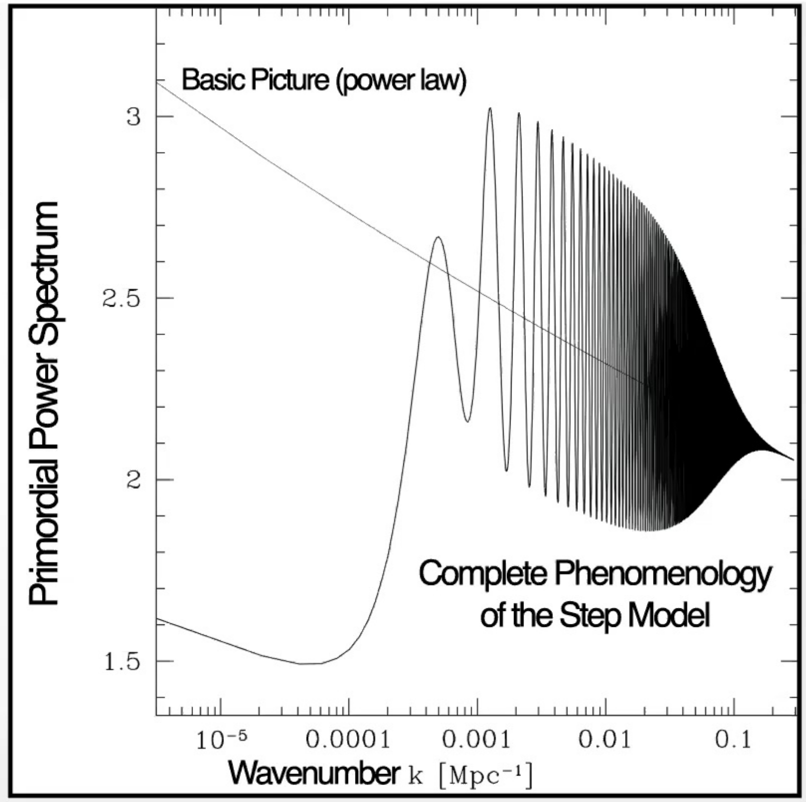
PHYSICAL REVIEW D **89**, 083529 (2014)

Inflationary steps in the Planck data

V Miranda[1,2] and Wayne Hu[3,1]
[1]*Department of Astronomy & Astrophysics, University of Chicago, Chicago, Illinois 60637, USA*
[2]*The Capes Foundation, Ministry of Education of Brazil, Brasília DF 70359-970, Brazil*
[3]*Kavli Institute for Cosmological Physics, Enrico Fermi Institute, University of Chicago, Chicago, Illinois 60637, USA*

Richer phenomenology





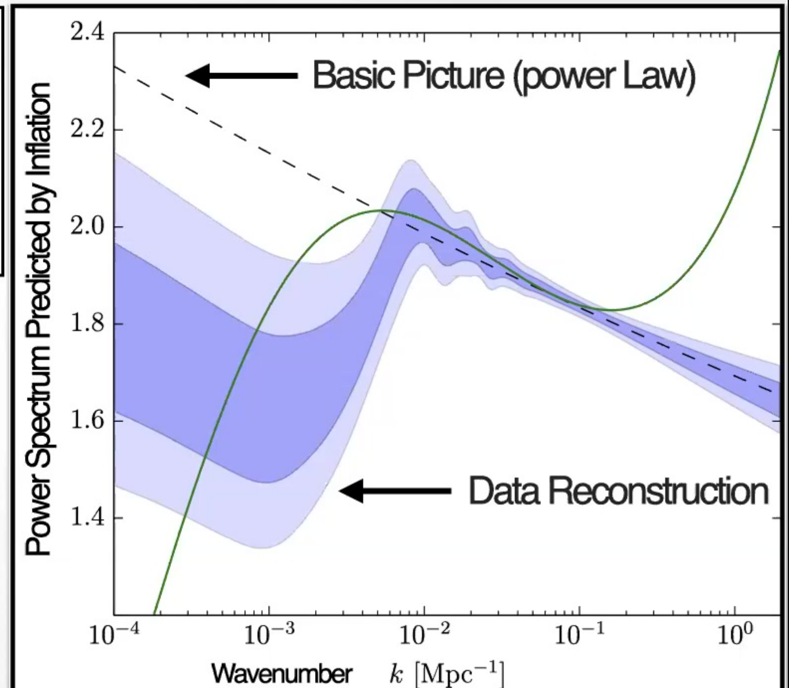
Examples of Inflation that violate the basic picture

PHYSICAL REVIEW D **96,** 083526 (2017)

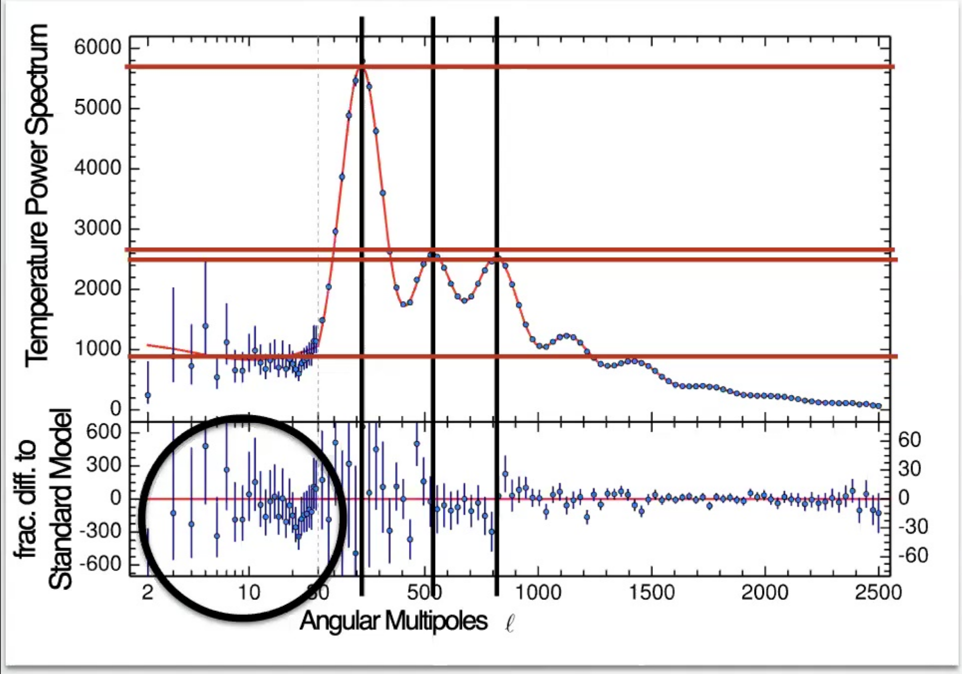
Inflationary features and shifts in cosmological parameters from *Planck* 2015 data

Georges Obied,[1] Cora Dvorkin,[1] Chen Heinrich,[2] Wayne Hu,[2] and V Miranda[3]
[1]*Harvard University, Department of Physics, Cambridge, Massachusetts 02138, USA*
[2]*Kavli Institute for Cosmological Physics, Department of Astronomy and Astrophysics, Enrico Fermi Institute, University of Chicago, Chicago, Illinois 60637, USA*
[3]*Center for Particle Cosmology, Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA*
(Received 7 July 2017; published 27 October 2017)

Current Experiment that measures the CMB prefers less power at large scales



How CMB mixes inferences about inflation x dark energy



Peak Positions

+

Peak amplitudes

relative

to the plateau

=>

Hubble Constant

H_0 = Local Rate of Cosmic Expansion

CMB mixes inferences on inflation vs dark energy

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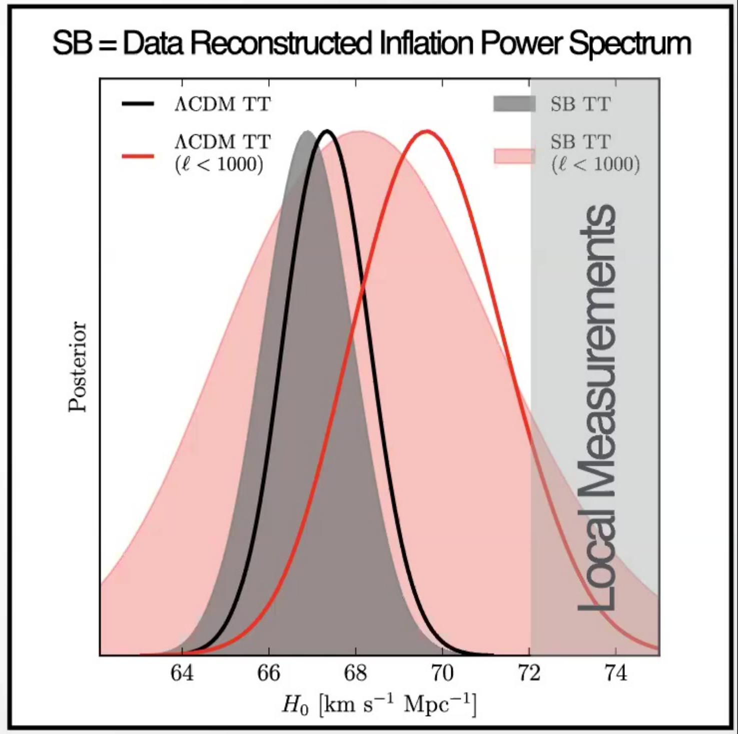


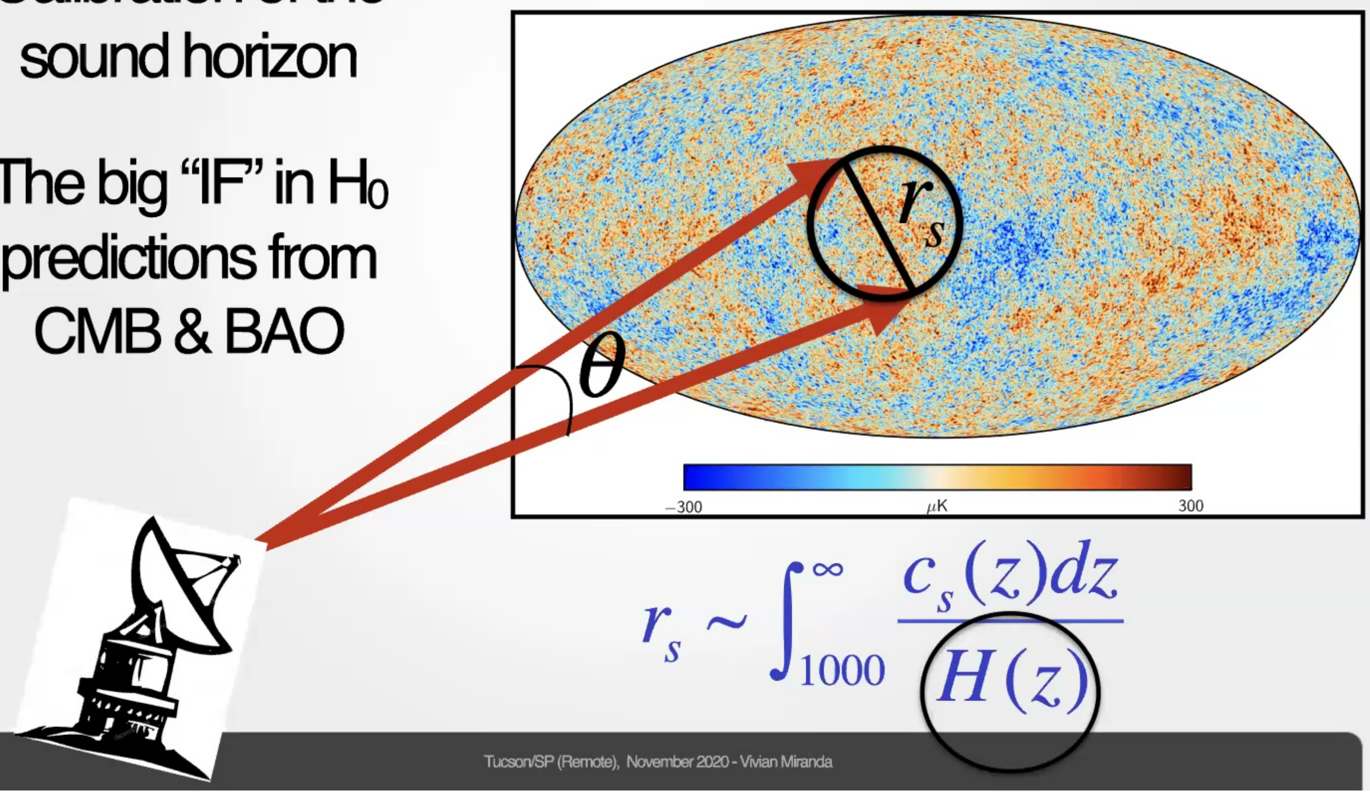
Hypotheses on inflation impact the Cosmic Microwave Background predictions on Dark Energy!

H_0 = Local Rate of Cosmic Expansion

Missing Physics in the Early Universe?

Calibration of the sound horizon

The big "IF" in H_0 predictions from CMB & BAO



$$r_s \sim \int_{1000}^{\infty} \frac{c_s(z)dz}{H(z)}$$

Coincidence problem? (H0 problem)

CMB VS BAO

CMB VS Local

Cosmology could be correct up to very low redshifts (z~0.01) then something abrupt happens

Something is missing on Dark Energy and/or Dark Matter

Something is missing on early universe (ex: Neff)

Coincidence problem? (H0 problem)

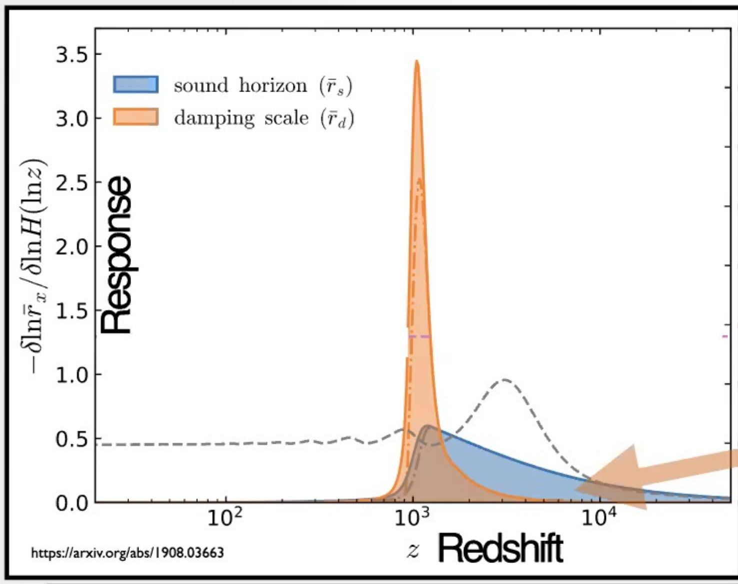
$$\frac{\Delta\left[\overbrace{\int_0^{1000} \frac{dz}{E(z)}}^{\text{CMB}}\right]}{\int_0^{1000} \frac{dz}{E(z)}} = \frac{\Delta\left[\overbrace{\int_0^{\sim 0.5} \frac{dz}{E(z)}}^{\text{BAO}}\right]}{\int_0^{\sim 0.5} \frac{dz}{E(z)}}$$

Dark Energy/Dark Matter relative importance on both integrals are different

$$E(z) \equiv H(z) / H_0$$

Dark Energy in the Early Universe?

What "IF" we are missing some physics at z >1000



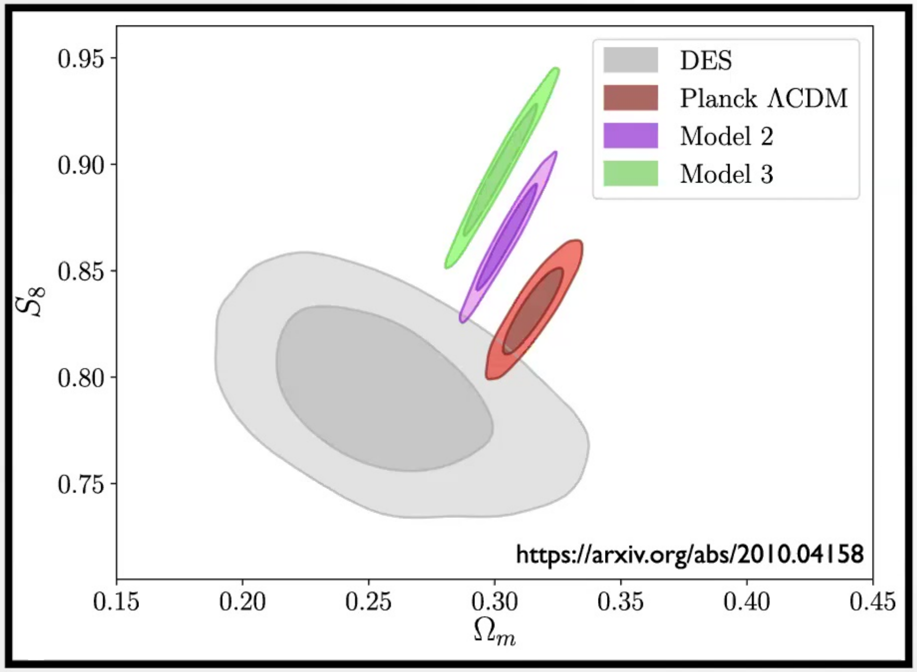
Challenge: CMB has a second scale, the damping horizon

Damping and sound horizons have different redshift dependency

Photons can't free stream because of Compton scattering at z >> 1000

Dark Energy in the Early Universe?

However….

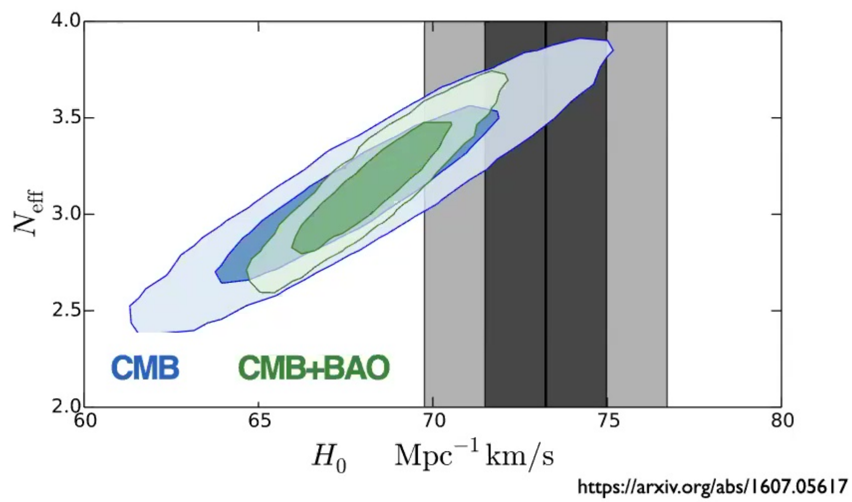


Single smoking gun might not be possible

But why C.C. in the late universe anyway?

Open to the possibility that standard model breaks at multiple redshifts

More radiation in the Early Universe?



H_0 = Local Rate of Cosmic Expansion

$N_{\rm eff}$

The amount of radiation (extra neutrino species) in the early universe affects the **background expansion** observed in the late Universe

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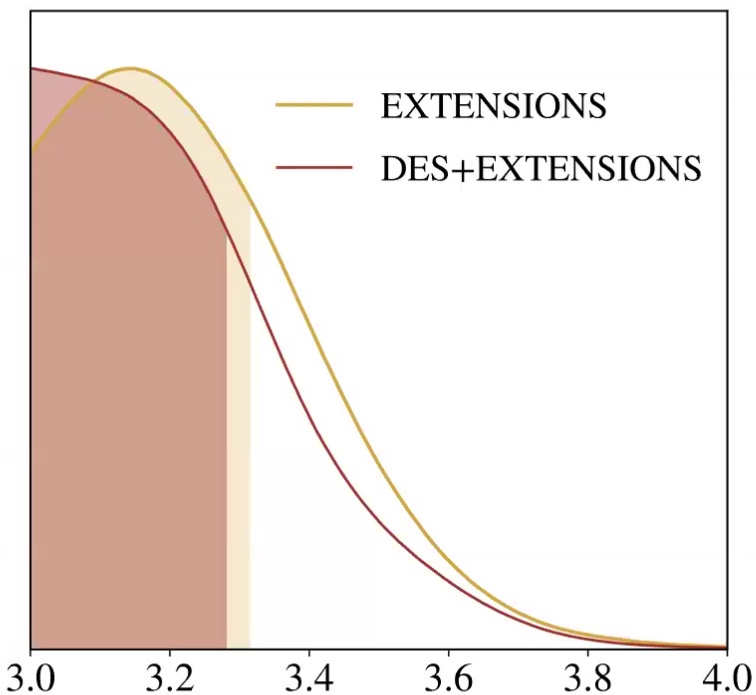
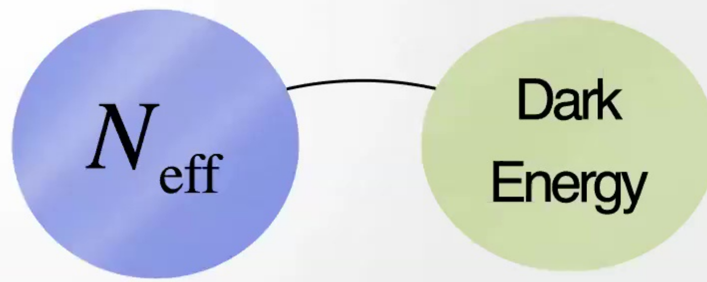
More radiation in the Early Universe?



$N_{eff} = 3$ is the standard model

The amount of radiation in the early universe affects Dark Energy predictions

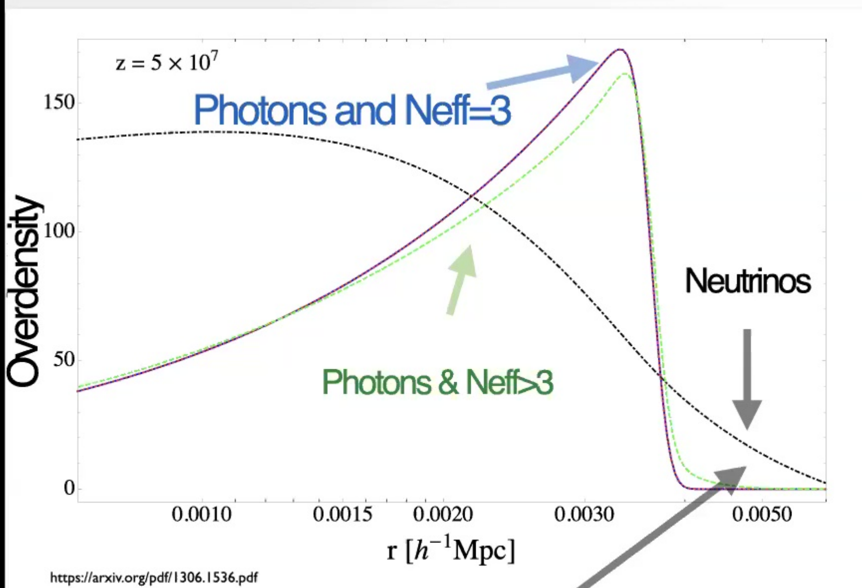


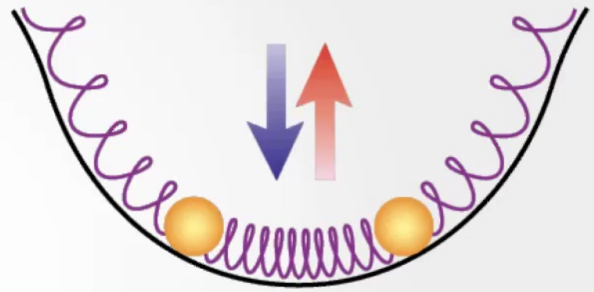
DES-2018-0376
FERMILAB-PUB-18-507-PPD

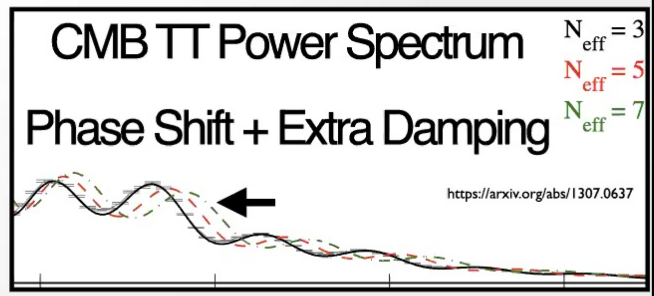
Dark Energy Survey Year 1 Results:
Constraints on Extended Cosmological Models from Galaxy Clustering and Weak Lensing

More radiation in the Early Universe?

Problem: Neutrinos are too fast!



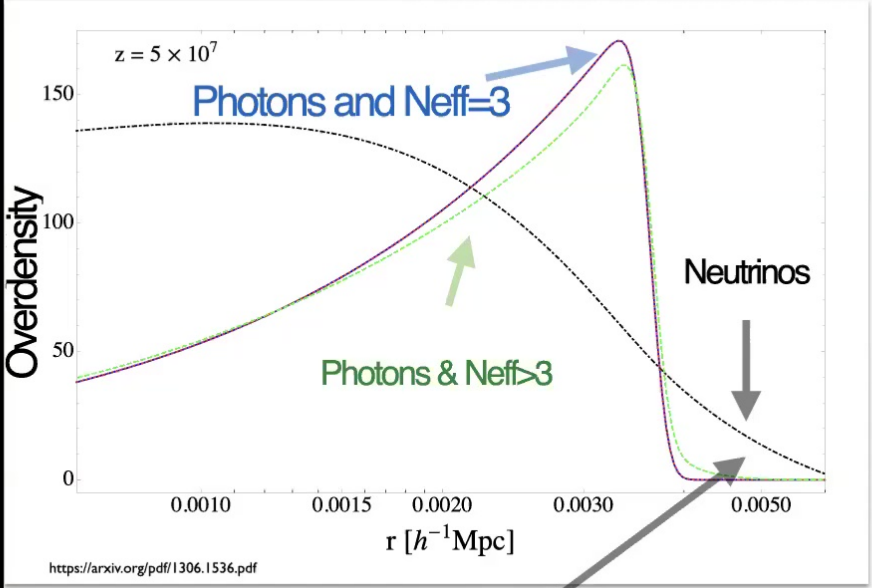


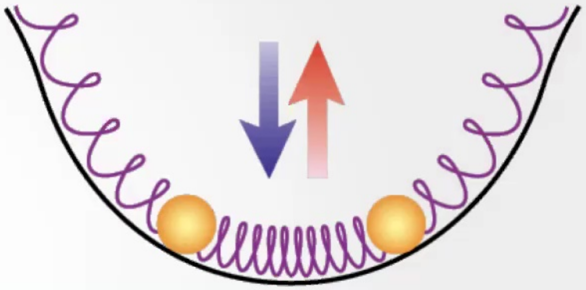


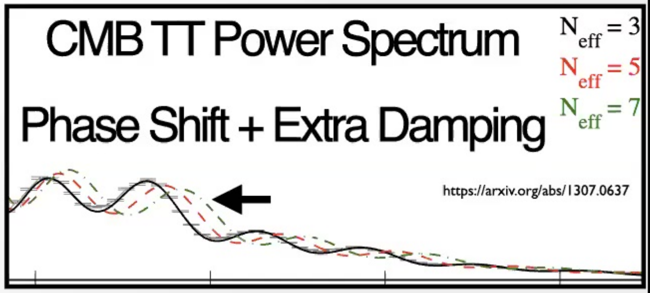
Significant contribution to Gravitational Potential
=> Pull photons => Phase and Amplitude shifts

More radiation in the Early Universe?

Problem: Neutrinos are too fast!







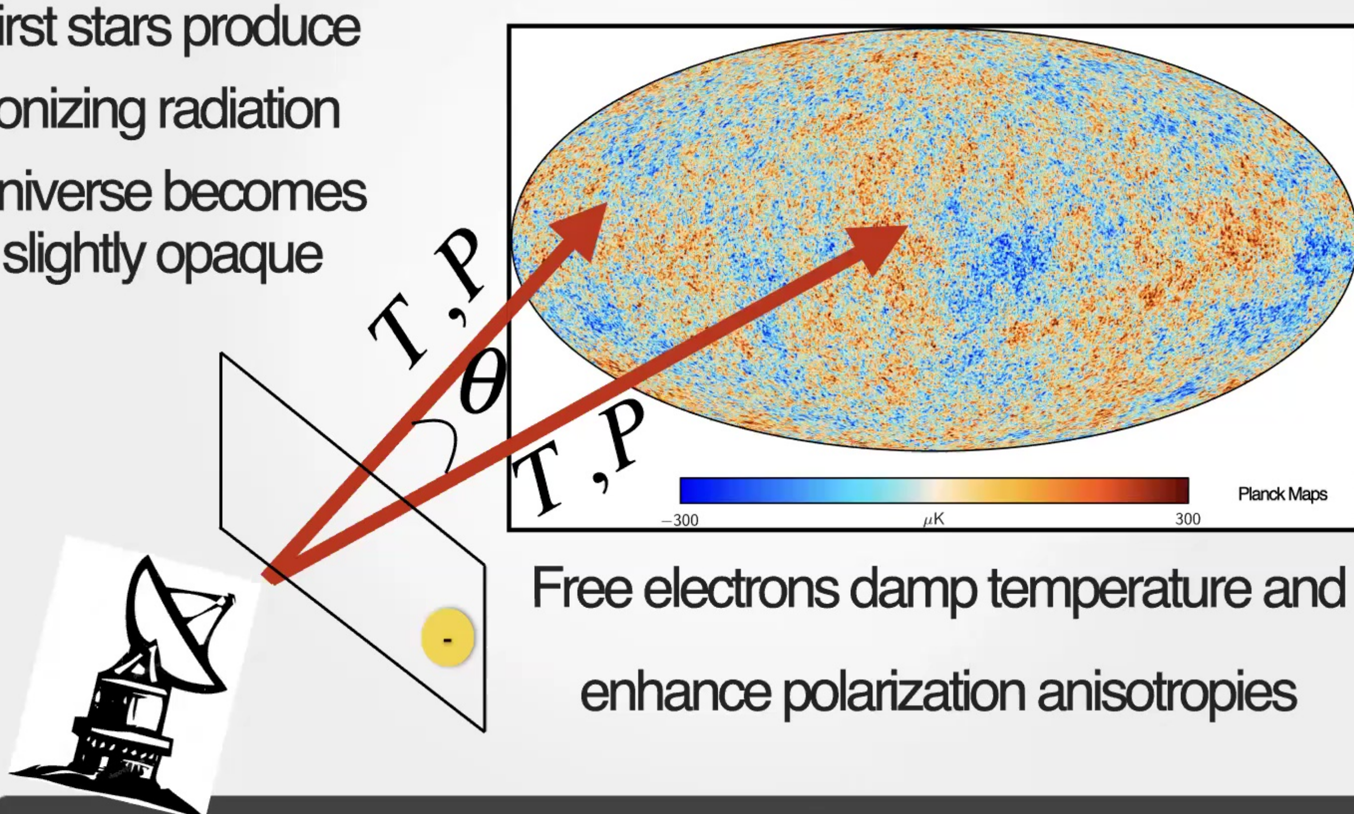
Significant contribution to Gravitational Potential
=> Pull photons => Phase and Amplitude shifts

Intermediate Universe

We probe Reionization w/ the Cosmic Microwave Background

First stars produce ionizing radiation

Universe becomes slightly opaque



Free electrons damp temperature and enhance polarization anisotropies

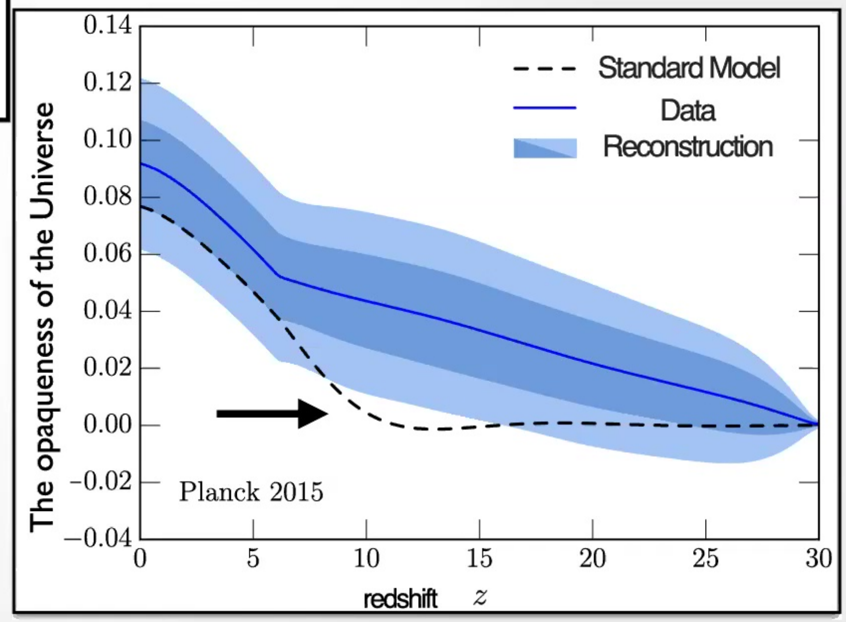
We probe Reionization w/ the Cosmic Microwave Background

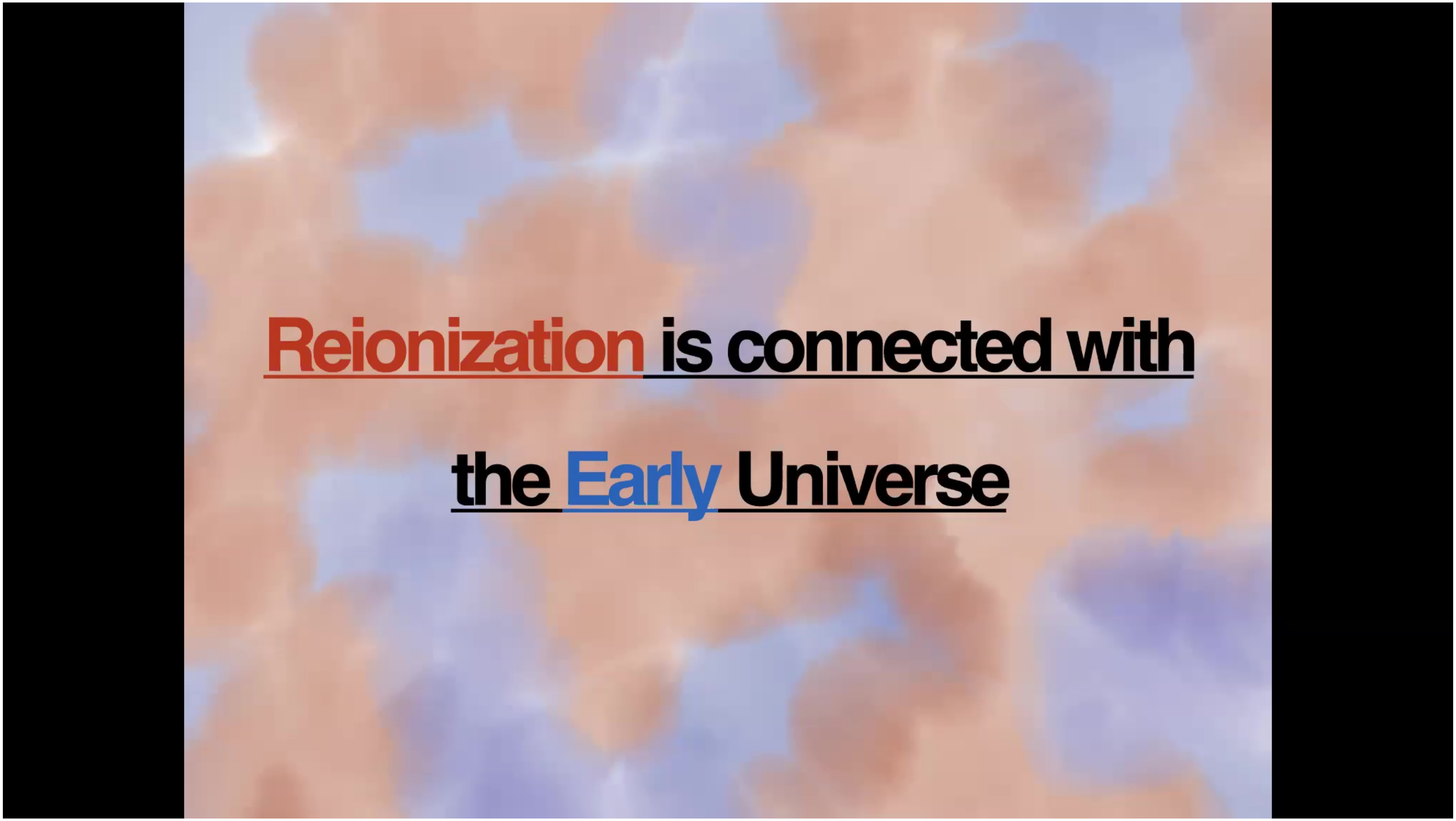
Complete reionization constraints from Planck 2015 polarization

Chen He Heinrich*,[1,2] V Miranda,[3] and Wayne Hu[4,5]
[1] Kavli Institute for Cosmological Physics, Enrico Fermi Institute, University of Chicago, Illinois 60637
[2] Department of Physics, University of Chicago, Illinois 60637, USA*
[3] Center for Particle Cosmology, Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA
[4] Kavli Institute for Cosmological Physics, Enrico Fermi Institute, University of Chicago, Chicago Illinois 60637, USA
[5] Department of Astronomy & Astrophysics, University of Chicago, Illinois 60637, USA
(Dated: April 10, 2017)

Hints of high redshift reionization signal

New sources such as decaying dark matter?



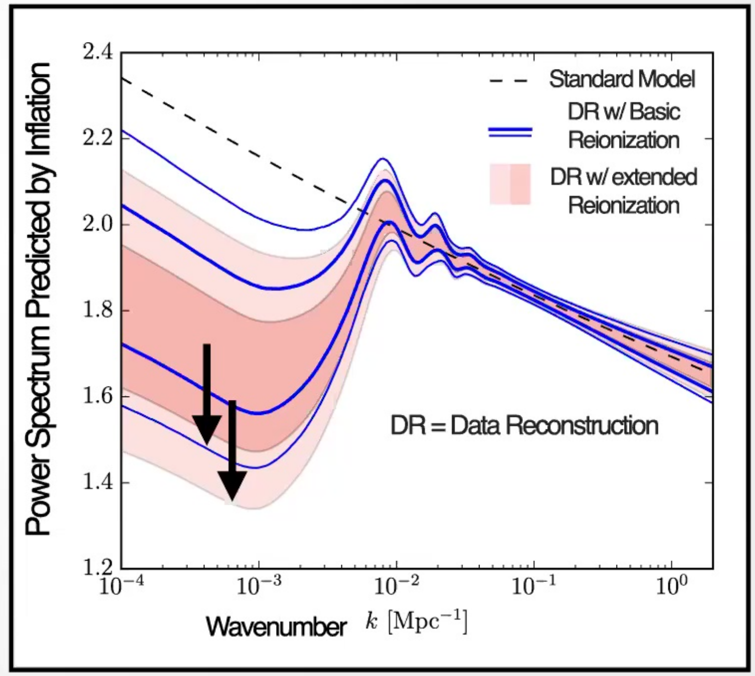

Reionization is connected with
the Early Universe

We showed how degenerate Reionization is with Inflation

Inflationary vs. Reionization Features from *Planck* 2015 Data

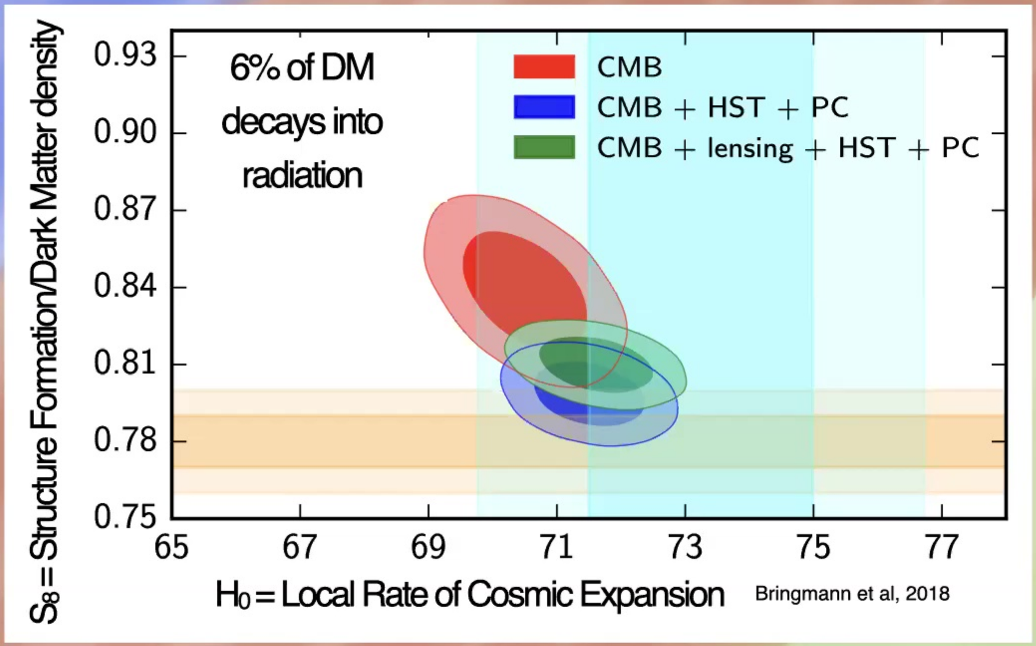
Georges Obied,[1] Cora Dvorkin,[1] Chen Heinrich,[2,3] Wayne Hu,[4] and V Miranda[5]
[1] *Harvard University, Department of Physics, Cambridge, MA 02138, USA*
[2] *California Institute of Technology, Pasadena California 91125*
[3] *Jet Propulsion Laboratory, Pasadena California 91109*
[4] *Kavli Institute for Cosmological Physics, Department of Astronomy & Astrophysics, Enrico Fermi Institute, University of Chicago, Chicago, IL 60637*
[5] *Center for Particle Cosmology, Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA*

Reionization affects the balance between scales in the Temperature Power Spectrum of the Cosmic Microwave Background, so does Inflation



Early

Model where a small fraction of Dark Matter can decay into radiation…



…during the Intermediate epoch can affect predictions for H_0 and S_8

Late

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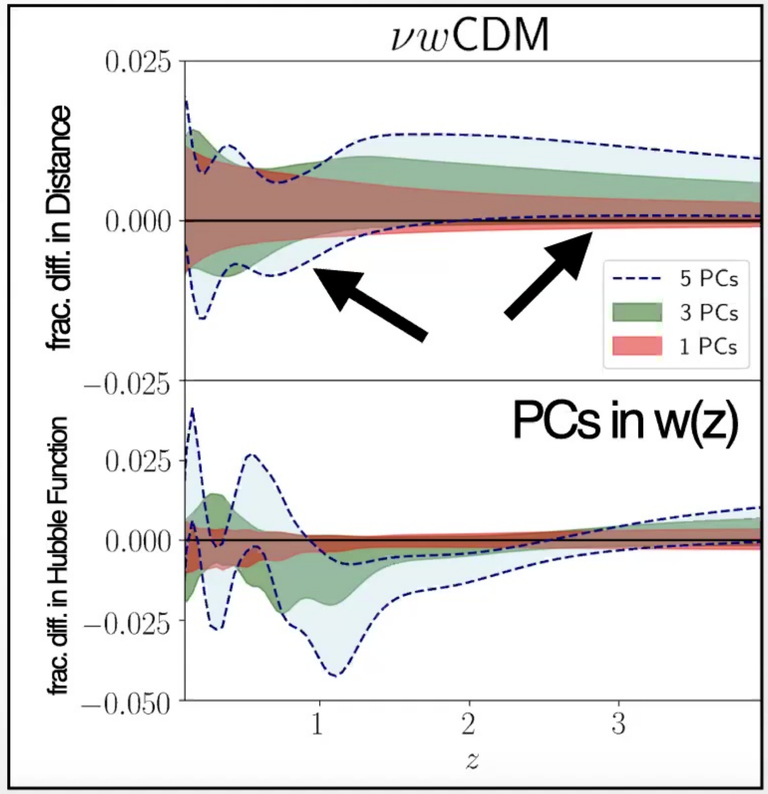
Proposed work on DESI: Dark Energy Spectroscopic Instrument

Observable Predictions for Massive-Neutrino Cosmologies with Model-Independent Dark Energy

Ana Diaz Rivero,[1,*] V. Miranda,[2,3,†] and Cora Dvorkin[1,‡]
[1]*Department of Physics, Harvard University, Cambridge, MA 02138, USA*
[2]*Steward Observatory, Department of Astronomy, University of Arizona, Tucson, Arizona, 85721, USA*
[3]*Center for Particle Cosmology, Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA*

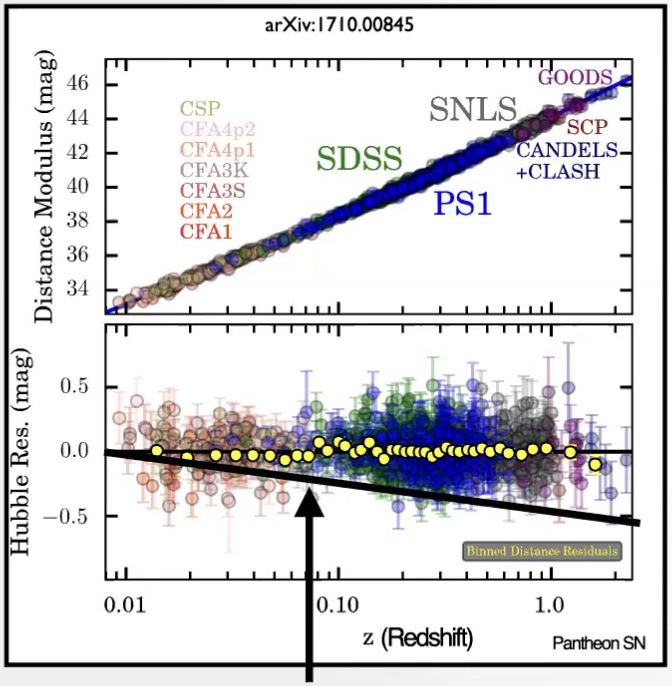
Hints that high redshift BAO can be used to help constrain physics in the intermediate universe even when we assume **wild** dark energy models.

Low-z signal completely degenerate



The Connected Universe: Relating Early, Intermediate and Late Universe with Cosmological Data
Seminar - Perimeter Institute
Vivian Miranda

Habemus Accelerationem: Type Ia supernovae are too dim



Type IA supernovae constrain the evolution of the background expansion

Latests surveys show the background expansion is close to LCDM up to a few percent!

Dark Matter Only $\Rightarrow \Delta \text{mag}(z=1) \sim -0.5$

Supernova can measure background evolution for a variety of D.E.

Cosmological model insensitivity of local H_0 from the Cepheid distance ladder

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[2] Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, PA 19104, USA
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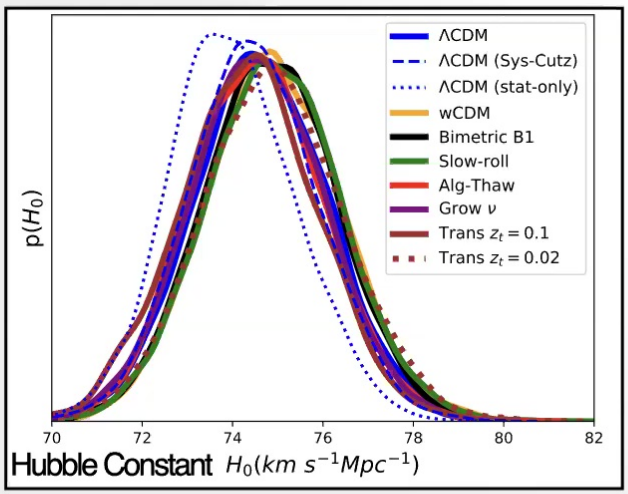
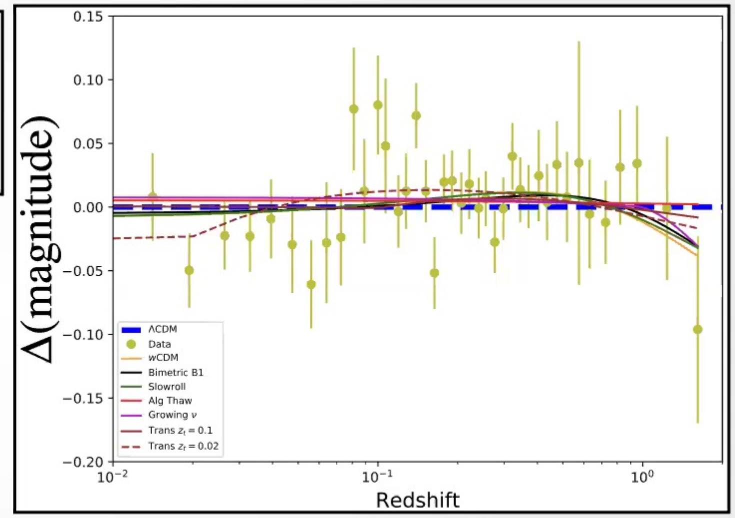
[5] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA
[6] Department of Physics and Astronomy, Johns Hopkins University, Baltimore, MD 21218, USA
[7] Steward Observatory, Department of Astronomy, University of Arizona, Tucson, Arizona, 85721, USA





First time: joint H0/SN covariance on the whole redshift range. We can now predict CMB sound horizon for different models using a direct distance ladder

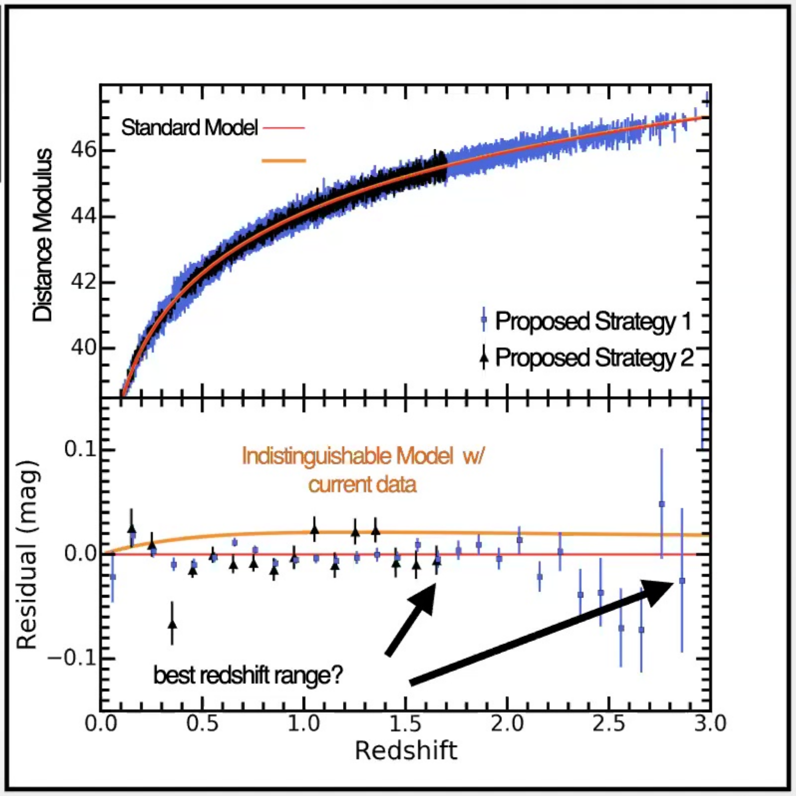
Supernova can measure background evolution for a variety of D.E.

Simulations of the *WFIRST* Supernova Survey and Forecasts of Cosmological Constraints

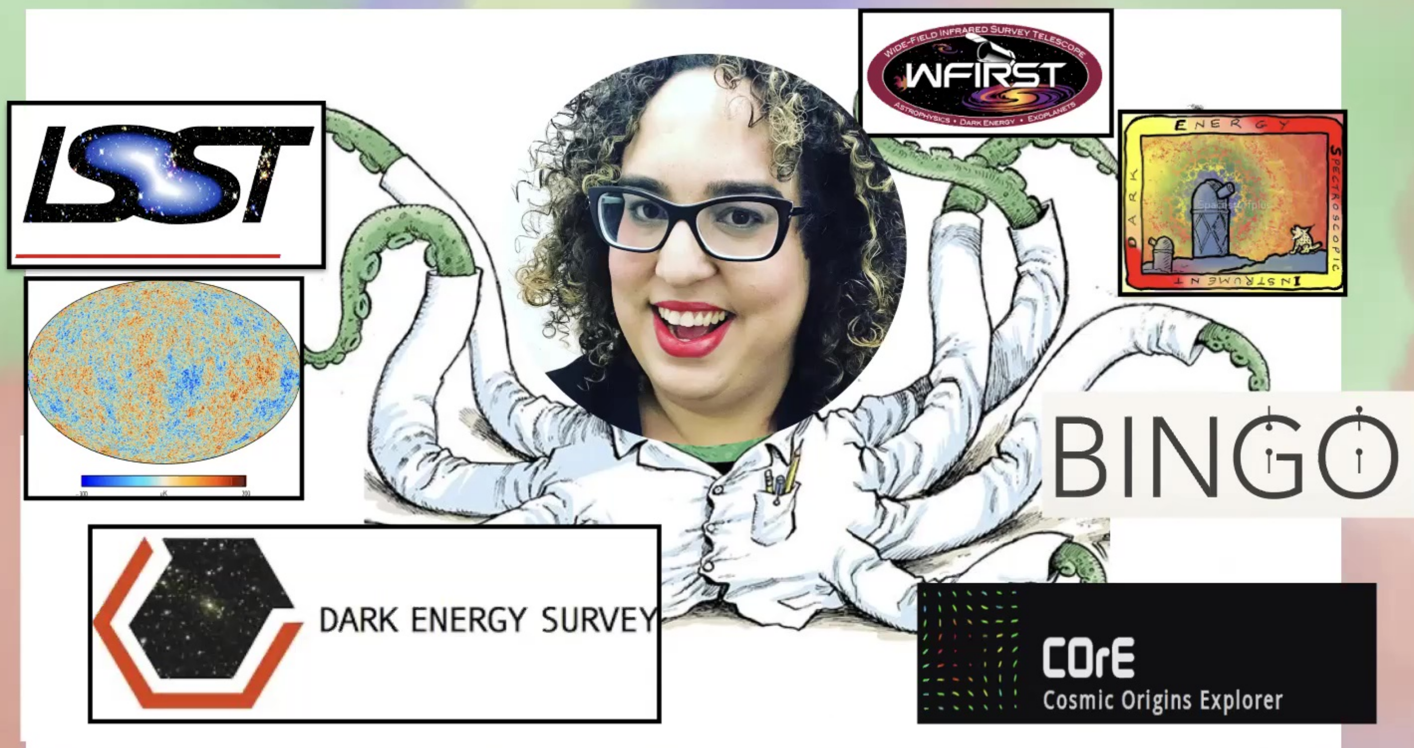
R. Hounsell[1,2,*] D. Scolnic[3], R. J. Foley[1], R. Kessler[3], V. Miranda[4], A. Avelino[5] R. C. Bohlin[6], A. V. Filippenko[7], J. Frieman[3,8], S. W. Jha[9], P. L. Kelly[7], R. P. Kirshner[5,11], K. Mandel[5], A. Rest[6], A. G. Riess[6,12], S. A. Rodney[10], L. Strolger[6]

State-of-the-art analysis

WFIRST can check if the background expansion is compatible with the Cosmological Constant to astonishing precision

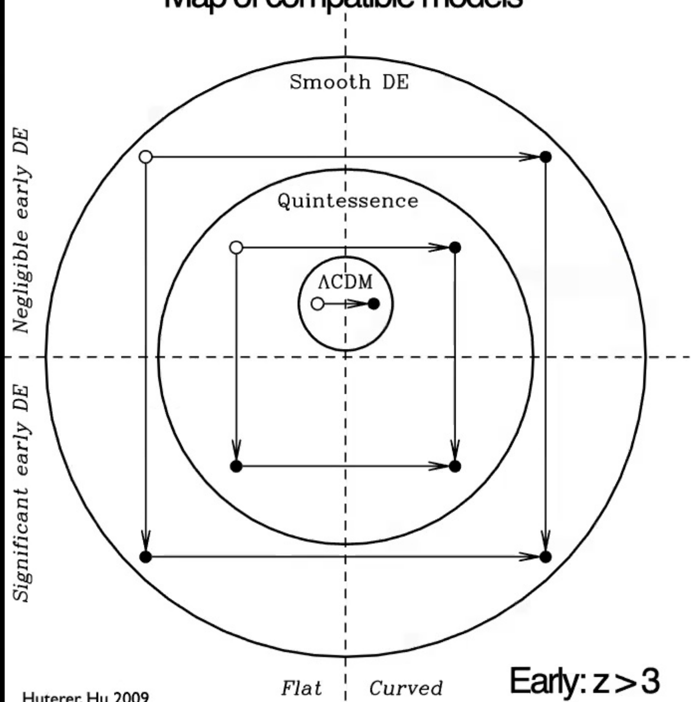


Data on background and on (linear and non-linear) structure formation needed



Generic approach to the acceleration problem

Map of compatible models



Huterer, Hu 2009

Early: $z > 3$

Simplest Paradigm of Cosmic Acceleration

- General Relativity
- Minimal coupling to Dark Matter
- Minimal coupling to the standard model
- Smooth Dark Energy (no clustering)

How can we falsify this Paradigm?

ΛCDM = Standard Model

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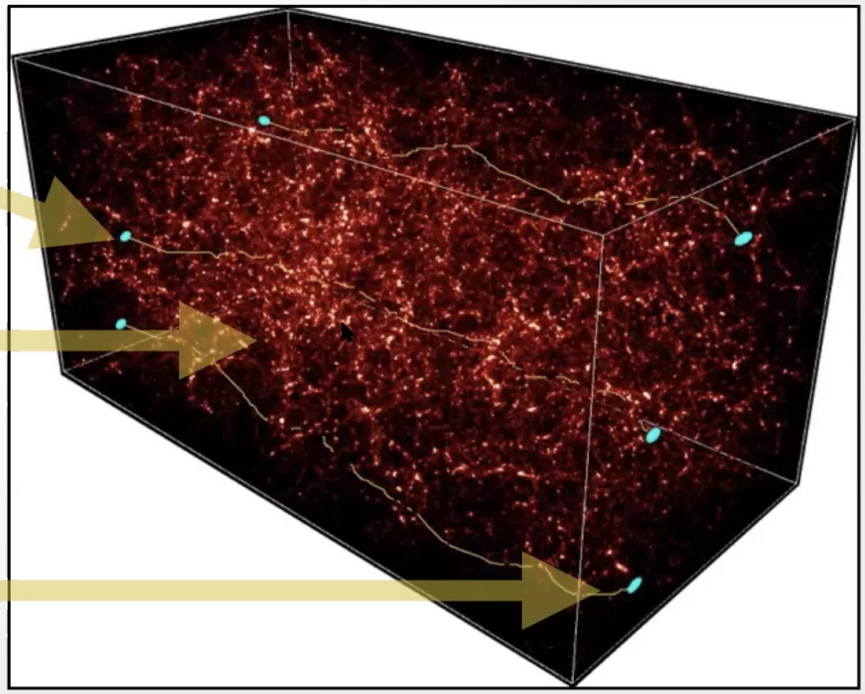
Gravitational Lensing By The Large Scale Structure

Measures the amplitude of structure formation in the late Universe

Source: Optical Galaxies

Lenses: Big Structures of Matter or Voids

Observables: Source galaxies with shaped lensed



$$\Delta_m^2(k,a) \propto \left[\frac{G^2(a)a^2}{\Omega_m^2}\right]\left[T^2(k)\right]\left[\Delta_{\mathcal{R}}^2(k)\right]$$

Matter Power Spectrum — Growth Factor — Transfer Function — Power Spectrum from Inflation

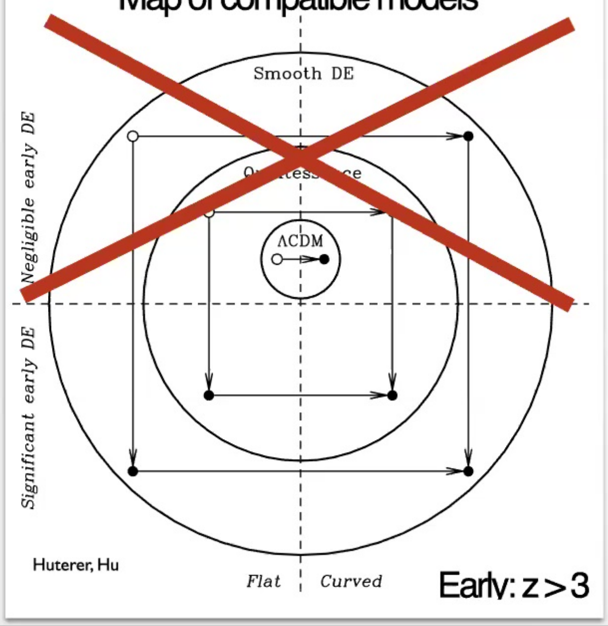
Strategy: Dark Energy Models predict consistency between the Growth Factor and Background Expansion

Work on WFIRST: - Wide Field Infrared Survey Telescope

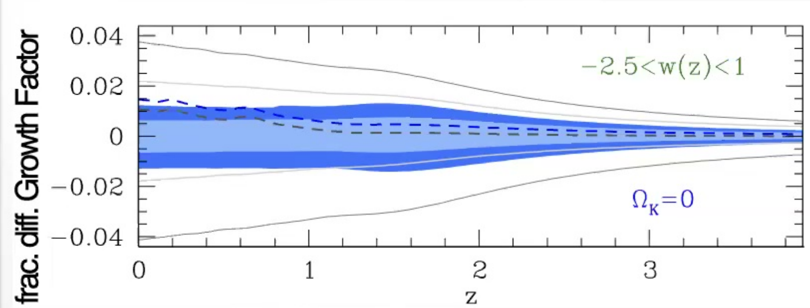
Model-Independent Predictions for Smooth Cosmic Acceleration Scenarios

V Miranda[1] and Cora Dvorkin[2]
[1] *Center for Particle Cosmology, Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA*
[2] *Harvard University, Department of Physics, Cambridge, MA 02138, USA*

Map of compatible models



WFIRST Type IA Supernovae so precise that the upper half of the map predicts growth factor that deviates from LCDM by only +- 5%



Solid lines (68% and 95% c.i.) are center at zero by construction. Dash lines = means

What if smooth dark energy fails to explain the data?

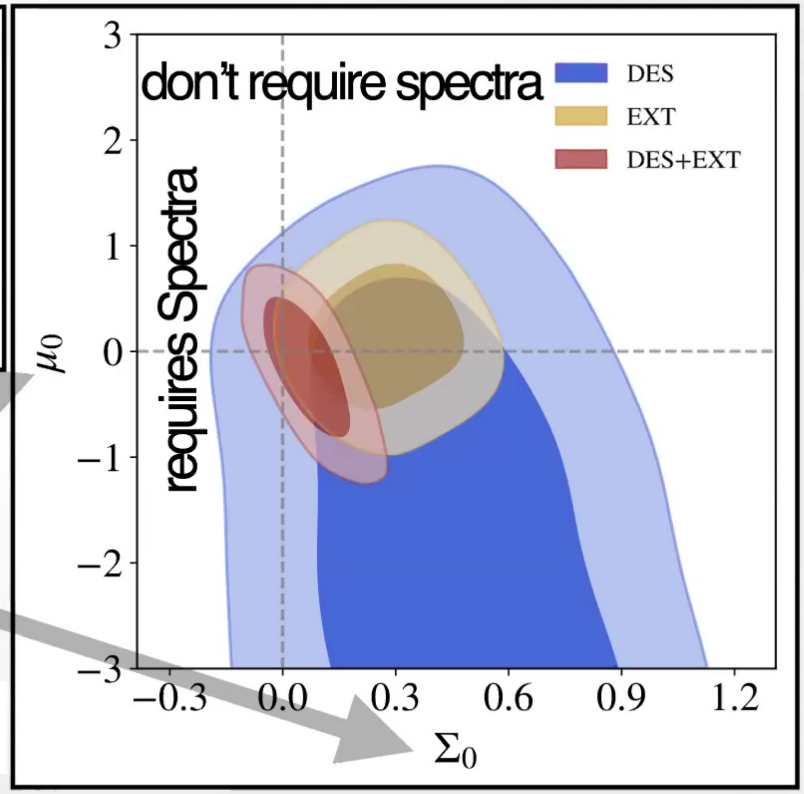
DES-2018-0376
FERMILAB-PUB-18-507-PPD

Dark Energy Survey Year 1 Results:
Constraints on Extended Cosmological Models from Galaxy Clustering and Weak Lensing

T. M. C. Abbott,[1] F. B. Abdalla,[2,3] S. Avila,[4] M. Banerji,[5,6] E. Baxter,[7] K. Bechtol,[8] M. R. Becker,[9] E. Bertin,[10,11] J. Blazek,[12,13] S. L. Bridle,[14] D. Brooks,[2] D. Brout,[7] D. L. Burke,[15,16] A. Campos,[17,18] A. Carnero Rosell,[19,20] M. Carrasco Kind,[21,22] J. Carretero,[23] F. J. Castander,[24,25] R. Cawthon,[26] C. Chang,[26] A. Chen,[27] M. Crocce,[24,25] C. E. Cunha,[15] L. N. da Costa,[20,19] C. Davis,[15] J. De Vicente,[28] J. DeRose,[29,15] S. Desai,[30] E. Di Valentino,[14] H. T. Diehl,[31] J. P. Dietrich,[32,33] S. Dodelson,[18] P. Doel,[2] A. Drlica-Wagner,[31] T. F. Eifler,[34,35] J. Elvin-Poole,[14,12] A. E. Evrard,[36,27] E. Fernandez,[23] A. Ferté,[37,38,39] B. Flaugher,[31] P. Fosalba,[25,24] J. Frieman,[31,26] J. García-Bellido,[40] D. W. Gerdes,[27,36] T. Giannantonio,[6,5,41] D. Gruen,[15,16] R. A. Gruendl,[21,22] J. Gschwend,[20,19] G. Gutierrez,[31] W. G. Hartley,[2,42] D. L. Hollowood,[43] K. Honscheid,[12,44] B. Hoyle,[45,41] D. Huterer,[27] B. Jain,[7] T. Jeltema,[43] M. W. G. Johnson,[22] M. D. Johnson,[22] A. G. Kim,[46] E. Krause,[35] K. Kuehn,[47] N. Kuropatkin,[31] O. Lahav,[2] S. Lee,[44,12] P. Lemos,[5,6] C. D. Leonard,[18] T. S. Li,[26,31] M. Lima,[19,48] H. Lin,[31] M. A. G. Maia,[19,20] J. L. Marshall,[49] P. Martini,[50,12] F. Menanteau,[22,21] C. J. Miller,[27,36] R. Miquel,[23,51] V. Miranda,[35] J. J. Mohr,[45,33,32] J. Muir,[15] R. C. Nichol,[4] B. Nord,[31] R. L. C. Ogando,[20,19] A. A. Plazas,[34] M. Raveri,[26] R. P. Rollins,[14] A. K. Romer,[52] A. Roodman,[15,16] R. Rosenfeld,[19,53] S. Samuroff,[18] E. Sanchez,[28] V. Scarpine,[31] R. Schindler,[16] M. Schubnell,[27] D. Scolnic,[26] L. F. Secco,[7] S. Serrano,[25,24] I. Sevilla-Noarbe,[28] M. Smith,[54] M. Soares-Santos,[55] F. Sobreira,[19,56] E. Suchyta,[57] M. E. C. Swanson,[22] G. Tarle,[27] D. Thomas,[4] M. A. Troxel,[12,44] V. Vikram,[9] A. R. Walker,[1] N. Weaverdyck,[27] R. H. Wechsler,[16,29,15] J. Weller,[32,45,41] B. Yanny,[31] Y. Zhang,[31] and J. Zuntz[37]
(DES Collaboration)

Modified Poisson equation

Modified lensing equation



Stay tuned in 2020 - DES Y3!

DES-2020-XX
FERMILAB-PUB-XX

Dark Energy Year 3 Results: constraints on modified gravity theories from multi-probes

What if smooth dark energy fails to explain the data?

Finding structure in the dark: Coupled dark energy, weak lensing, and the mildly nonlinear regime

V Miranda,[1,*] Mariana Carrillo González,[1,†] Elisabeth Krause,[2,‡] and Mark Trodden[1,§]
[1]*Center for Particle Cosmology, Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA*
[2]*Kavli Institute for Particle Cosmology and Astrophysics, Stanford University, Stanford, California 94305, USA*

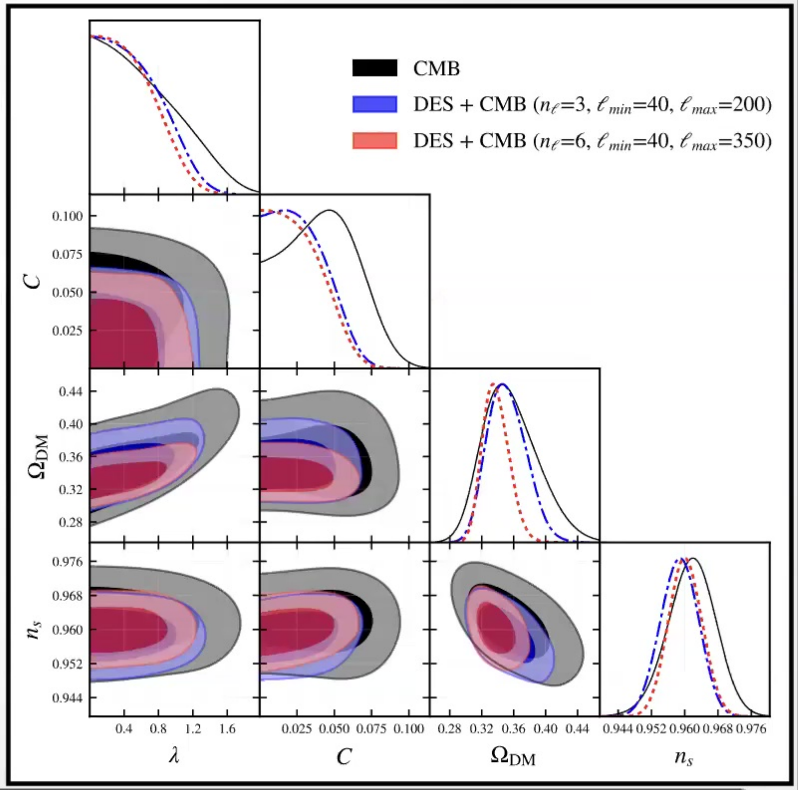
Scalar Field = Dark Energy

$$\mathcal{L}^{\rm eff}_{\rm DM} \propto e^{C\phi}\rho_{\rm DM}$$

Non-Minimal Coupling

Equation of State

$$w_{\rm DE} \approx -1 + \frac{\lambda^2}{3}$$



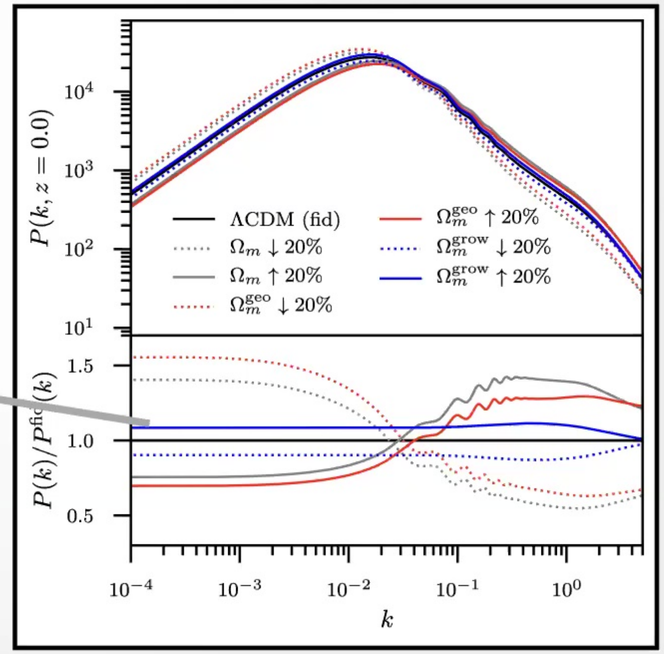
Work on DES - The Dark Energy Survey

Growth-Geometry Split: Consistency Between Background/Perturbations

$$G(a) = f(\Omega_m^{\text{growth}}, w_{\text{DE}}^{\text{growth}}, \ldots)$$

$$D_L, D_A = f(\Omega_m^{\text{geometry}}, w_{\text{DE}}^{\text{geometry}}, \ldots)$$

In LCDM: growth factor is a constant multiplicative factor in the linear regime



Jessica Muir

E. Baxter

V. Miranda

Internal Review phase in DES

Work on DES - The Dark Energy Survey

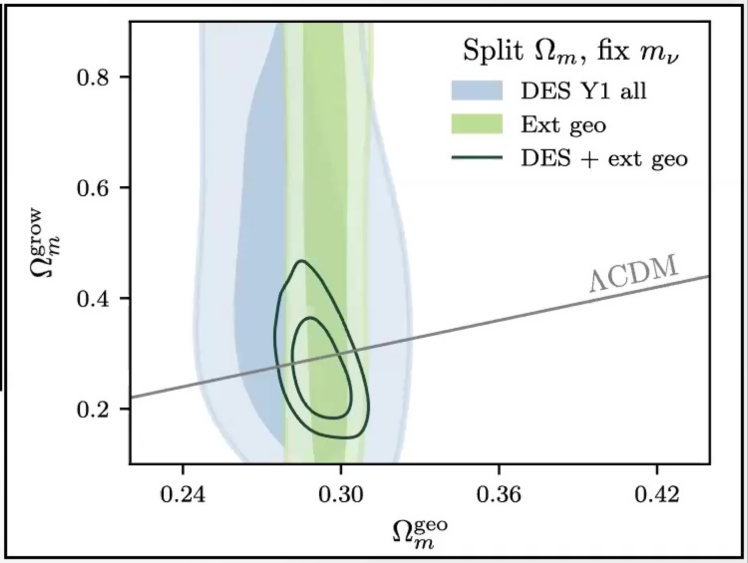
Growth-Geometry Split: Consistency Between Background/Perturbations

DES-2019-0520
FERMILAB-PUB-20-529-AE

DES Y1 results: Splitting growth and geometry to test ΛCDM

J. Muir,[1,*] E. Baxter,[2] V. Miranda,[3] C. Doux,[4] A. Ferté,[5] C. D. Leonard,[6] D. Huterer,[7] B. Jain,[4] P. Lemos,[8] M. Raveri,[9] S. Nadathur,[10] A. Campos,[11,12] A. Chen,[7] S. Dodelson,[11] J. Elvin-Poole,[13,14] S. Lee,[15] L. F. Secco,[4] M. A. Troxel,[15] N. Weaverdyck,[7] J. Zuntz,[16] D. Brout,[17,18] A. Choi,[13] M. Crocce,[19,20] T. M. Davis,[21] D. Gruen,[22,1,23] E. Krause,[3] C. Lidman,[24,25] N. MacCrann,[13,14] A. Möller,[26] J. Prat,[27] A. J. Ross,[13] M. Sako,[4] S. Samuroff,[11] C. Sánchez,[4] D. Scolnic,[15] B. Zhang,[25] T. M. C. Abbott,[28] M. Aguena,[29,30] S. Allam,[31] J. Annis,[31] S. Avila,[32] D. Bacon,[10] E. Bertin,[33,34] S. Bhargava,[35] S. L. Bridle,[36] D. Brooks,[8] D. L. Burke,[1,23] A. Carnero Rosell,[37,38] M. Carrasco Kind,[39,40] J. Carretero,[41] R. Cawthon,[42] M. Costanzi,[43,44] L. N. da Costa,[30,45] M. E. S. Pereira,[7] S. Desai,[46] H. T. Diehl,[31] J. P. Dietrich,[47] P. Doel,[8] J. Estrada,[31] S. Everett,[48] A. E. Evrard,[49,7] I. Ferrero,[50] B. Flaugher,[31] J. Frieman,[31,9] J. García-Bellido,[32] T. Giannantonio,[51,52] R. A. Gruendl,[39,40] J. Gschwend,[30,45] G. Gutierrez,[31] S. R. Hinton,[21] D. L. Hollowood,[48] K. Honscheid,[13,14] B. Hoyle,[47,53,54] D. J. James,[55] T. Jeltema,[48] K. Kuehn,[56,57] N. Kuropatkin,[31] O. Lahav,[8] M. Lima,[29,30] M. A. G. Maia,[30,45] F. Menanteau,[39,40] R. Miquel,[58,41] R. Morgan,[42] J. Myles,[22] A. Palmese,[31,9] F. Paz-Chinchón,[51,40] A. A. Plazas,[59] A. K. Romer,[35] A. Roodman,[1,23] E. Sanchez,[60] V. Scarpine,[31] S. Serrano,[19,20] I. Sevilla-Noarbe,[60] M. Smith,[61] E. Suchyta,[62] M. E. C. Swanson,[40] G. Tarle,[7] D. Thomas,[10] C. To,[22,1,23] D. L. Tucker,[31] T. N. Varga,[53,54] J. Weller,[53,54] and R.D. Wilkinson[35]
(DES Collaboration)

https://arxiv.org/pdf/2010.05924.pdf



The highly non-trivial collapse of contours due to the need of anchors in the early and late-time Universe!

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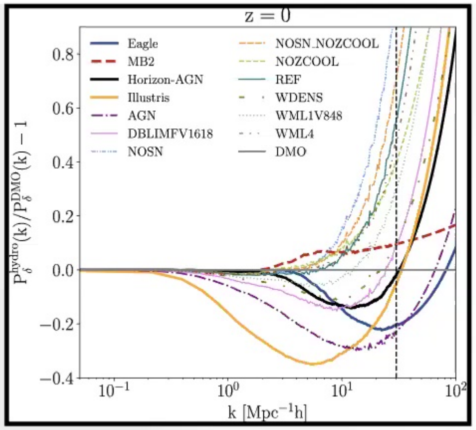
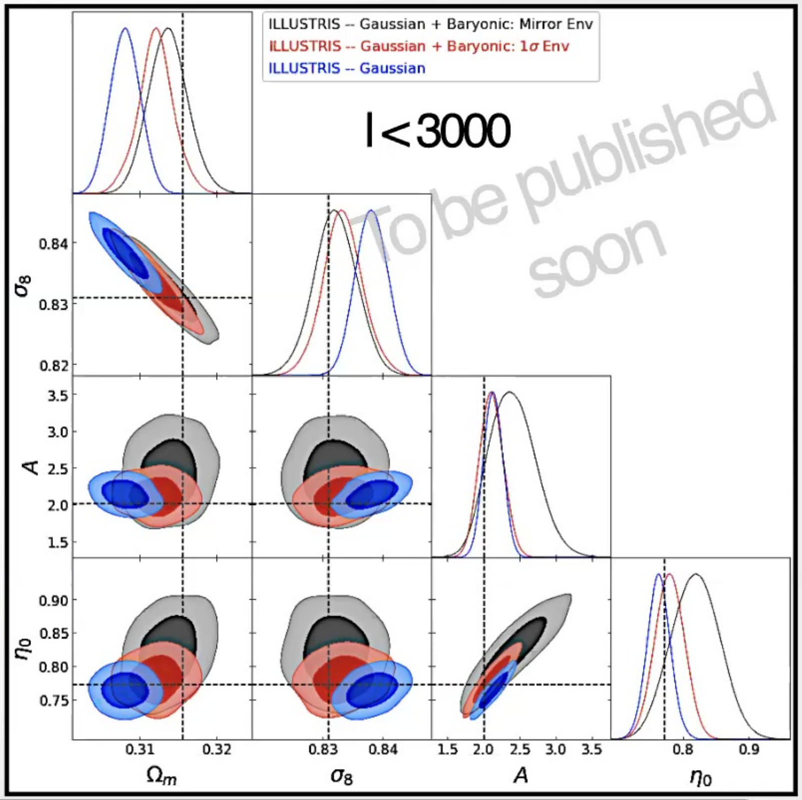
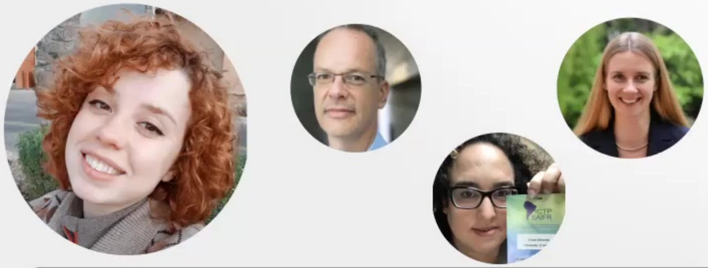
Work on LSST - Assessing Baryonic Impacts





Master thesis written by Maria Gabriela at ICTP-SAIFR with R. Rosenfeld, V. Miranda & E. Krause

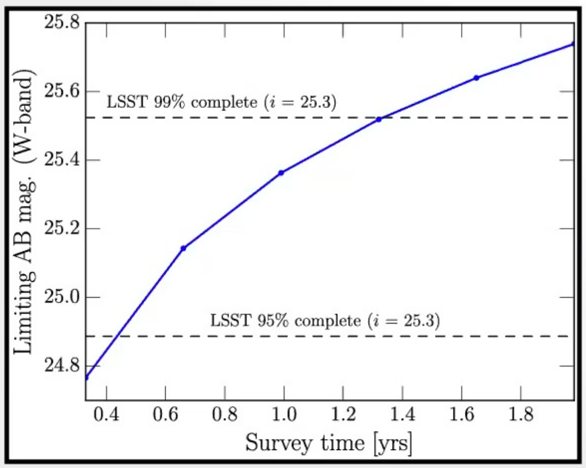


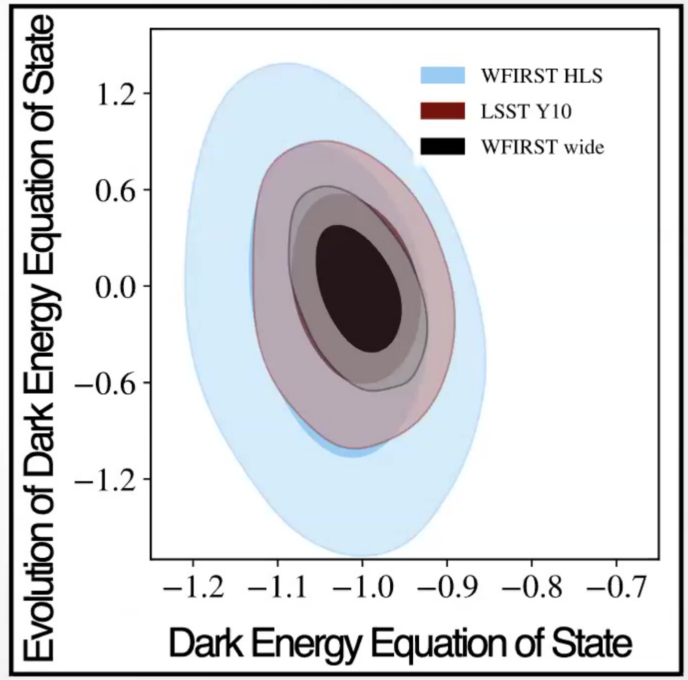
Work on WFIRST: Wide Field Infrared Survey Telescope

Cosmology with the Wide-Field Infrared Survey Telescope - Synergies with the Large Synoptic Survey Telescope

Tim Eifler[1★], Melanie Simet[2,3], Elisabeth Krause[1,4], Christopher Hirata[5], Rachel Mandelbaum[6], Hung-Jin Huang[1], Vivian Miranda[1], Cyrille Doux[7], Chen Heinrich[3], Eric Huff[3], Hironao Miyatake[3,8,9,10], Shoubaneh Hemmati[3], Xiao Fang[1], Paul Rogozenski[4], Jiachuan Xu[1], Peter Capak[12], Ami Choi[5], Olivier Doré[3,11], Bhuvnesh Jain[7], Mike Jarvis[7], Niall MacCrann[5], Dan Masters[3], Eduardo Rozo[4], David N. Spergel[13,14], Michael Troxel[15], Anja von der Linden[16], Yun Wang[12], David Weinberg[5],

Synergy between area (LSST) and depth (WFIRST)





Tensions: how to make sense of them?

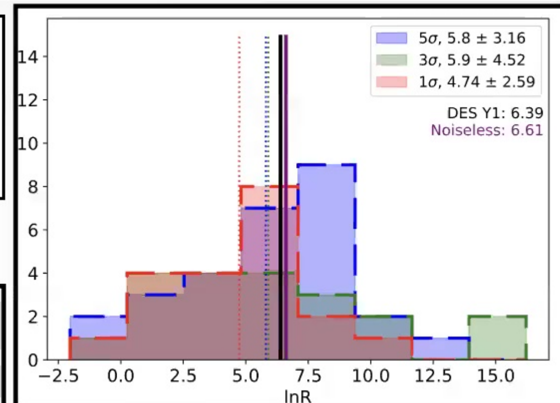
Interpreting Internal Consistency of DES Measurements

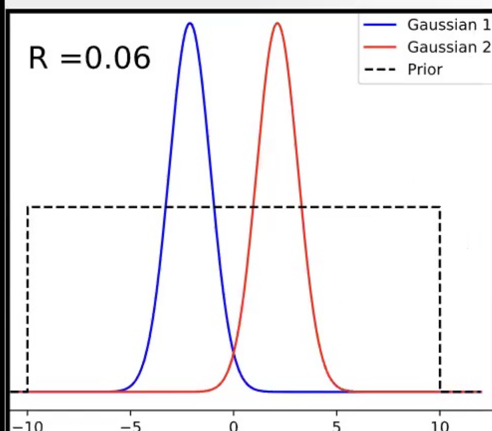
V. Miranda,[1★] P. Rogozenski,[2] and E. Krause[1,2]

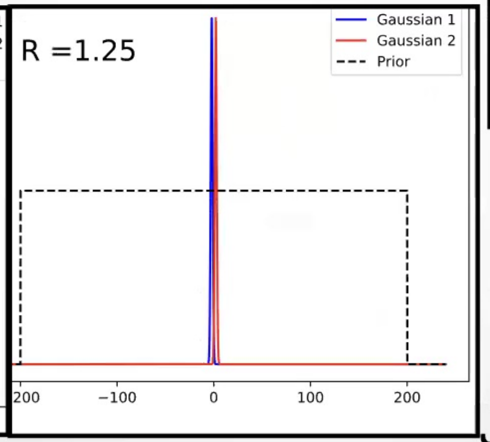
[1] *Steward Observatory, Department of Astronomy, University of Arizona, Tucson, Arizona, 85721, USA*

[2] *Department of Physics, University of Arizona, Tucson, Arizona, 85721, USA*

https://arxiv.org/abs/2009.14241



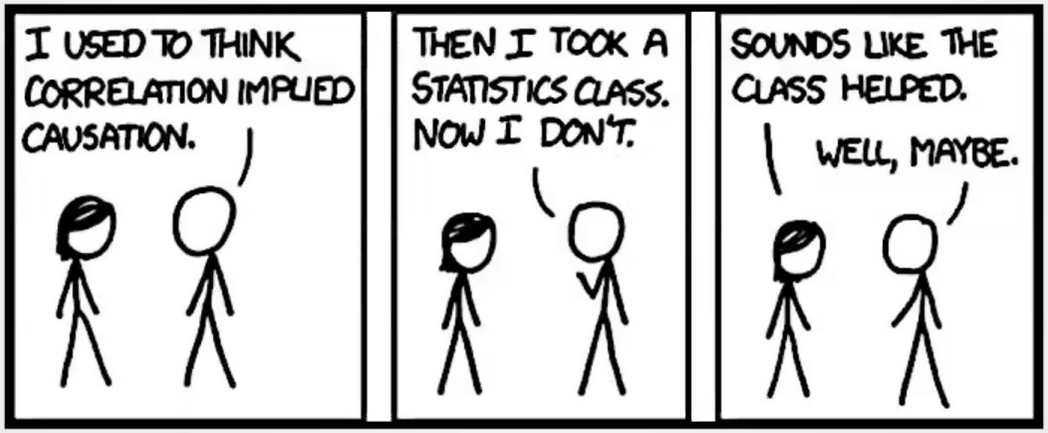




Priors that are too large and unrealistic can "hide" tensions.

Jeffrey scale must be calibrated

Tensions: how to make sense of them?



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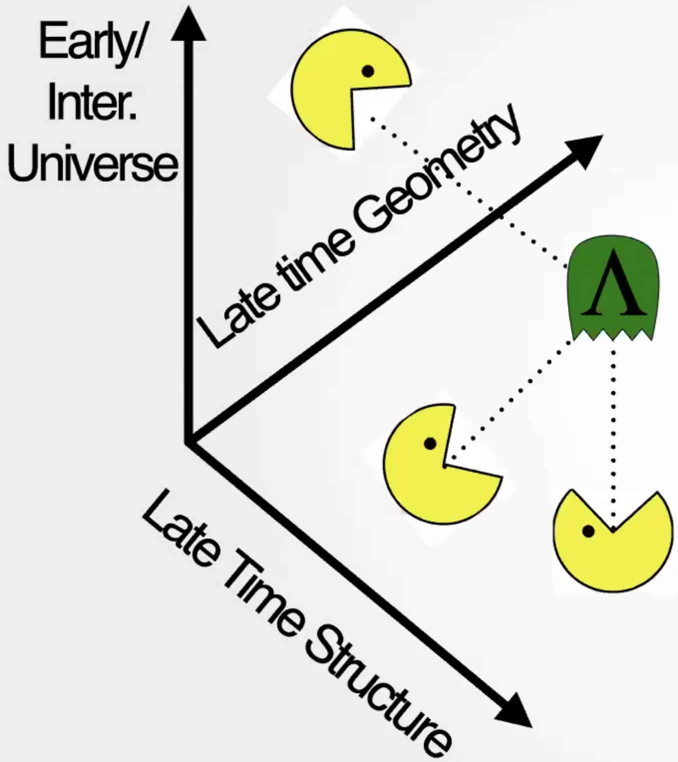

Λ = cosmological constant

Thank You