Joel Primack - Distinguished Professor of Physics Emeritus, UCSC

Current Research Areas

[Bio and Research Website]

Galaxy Formation and Evolution - We compare high-resolution simulations with observations using the latest observations from Hubble Space Telescope and ground-based observatories, and novel methods of machine learning, with support from NASA, DOE, and Google. We discovered why galaxies start pickle-shaped, and we try to understand how galaxies evolve, including roles of the supermassive black holes at their centers and the evolution of the circum-galactic medium (CGM).

- We co-lead the AGORA project comparing galaxy formation simulations by leading codes.

Collaborators include Avishai Dekel, Sandra Faber, David Koo, Marc Huertas-Company, Daniel Ceverino, Piero Madau, Xavier Prochaska, Nir Mandelker, Ji-hoon Kim, Susan Kassin, Greg Snyder, Rachel Somerville

Cosmology and Large Scale Structure - An episode of Early Dark Energy can resolve the tension between near and far measurements of the cosmic expansion rate H_0. We're using NASA's Pleiades supercomputer to determine the implications of EDE for formation of galaxies and clusters.

- What are the connections between dark matter halos and the galaxies that they host?

Collaborators include Marc Kamionkowski, Anatoly Klypin, Peter Behroozi, Aldo Rodriguez-Puebla

Habitable Planets and Radioactivity - More than half the internal heat of the earth comes from ^{232}Th and ^{238}U. Such heavy r-process elements are produced in neutron star mergers which are quite rare, so their abundance must vary a lot in different planetary systems. What are the implications for planetary magnetic fields and plate tectonics, which may be necessary for evolution of complex life?

Collaborators include Francis Nimmo, Enrico Ramirez-Ruiz, Mohammad Safarzadeh

My Current UCSC Grad Students & Their Research Projects **- James Kakos** Measuring Environment Density Around Distant Galaxies, **Viraj Pandya** New Semi-Analytic Models for Galaxy Evolution, **David Reiman** Astronomical Applications of Machine Learning, **Clayton Strawn** The CGM as a Test of Galaxy Formation Simulations

Face recognition for galaxies: Artificial intelligence brings new tools to astronomy

A 'deep learning' algorithm trained on realistic images from our cosmological simulations like those at the right has been surprisingly successful at classifying real galaxies in Hubble images. We also found that transitions between three stages of galaxy evolution seen at the right occur in galaxies observed by Hubble Space Telescope (HST) at the same stellar masses as in our high-resolution simulations.

Huertas-Company, Primack, et al. 2018

Examples of simulated galaxy evolution through the 3 stages: Pre-Blue Nugget (often elongated, i.e. pickle shaped), Blue Nugget (compaction phenomenon: gas infall leads to central starburst), and Post-Blue Nugget (often with star-forming disk), with similar galaxies observed by Hubble Space Telescope. The width of each image is approximately 100,000 light years. Credits: simulations Daniel Ceverino and Joel Primack, simulated images Greg Snyder and Marc Huertas-Company, HST observations CANDELS.

HST has played a major role in measuring the late-universe value of the present-epoch Hubble parameter H_0, and our research can lay the groundwork for HST and JWST to resolve the tension with the early-universe measurements.

There is serious tension between the value of the current-epoch Hubble parameter $H_0 \sim 73$ km/s/Mpc from late-universe measurements and the value $H_0 \sim 67$ measured by extrapolating cosmic microwave background and other early-universe measurements to the present epoch (Figure 1 Left). Of the approaches that have been suggested to resolve this tension, one that seems both physically plausible and easy to implement is a brief period of early dark energy (EDE) contributing a maximum of about 10% to the total energy density of the universe for a few thousand years around the time of matter domination (Figure 1 Right). We propose to investigate the observable astrophysical implications of this approach by running high-resolution cosmological simulations and filling the resulting halos and subhalos with realistic galaxies. Our preliminary results (Figure 2)show that ΛCDM+EDE results in significantly earlier structure formation than standard ΛCDM. It also changes galaxy clustering, including increasing the baryon acoustic oscillation length scale. The new high-resolution cosmological simulations we are doing on NASA's Pleiades supercomputer, updating our earlier Bolshoi-Planck and MultiDark-Planck simulations, can help to lay the groundwork for HST and JWST to resolve the tension with the early-universe measurements.

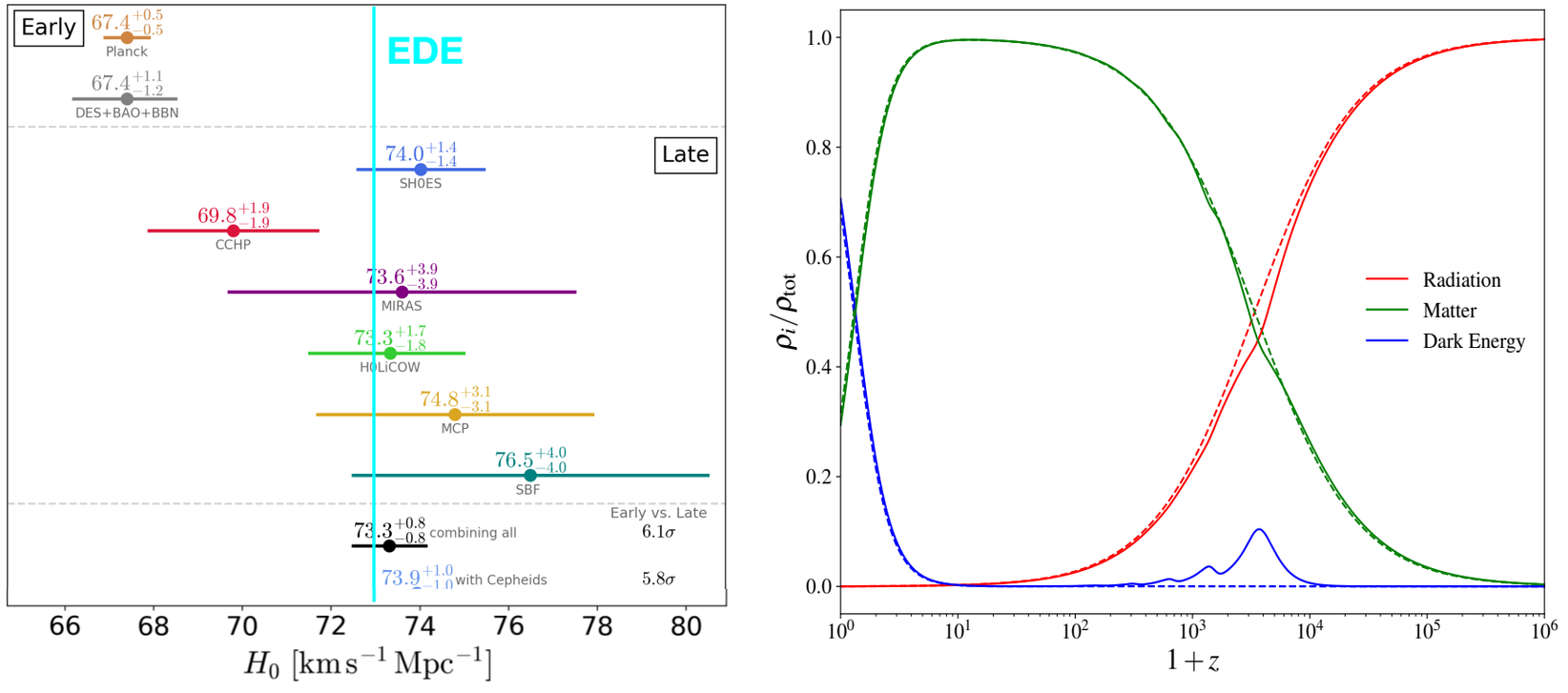

Figure 1: **Left** Recent measurements of H_0, both Early and Late (from Verde et al. 2019). **Right** Comparison of the evolution of cosmic densities of radiation, matter, and dark energy in units of critical density vs. $1+z$, using the version of ΛCDM+EDE from Smith et al. (2019), with the cosmological parameters in the top row of the Table in Fig. 2 (solid curves), compared with standard ΛCDM (dashed curves).

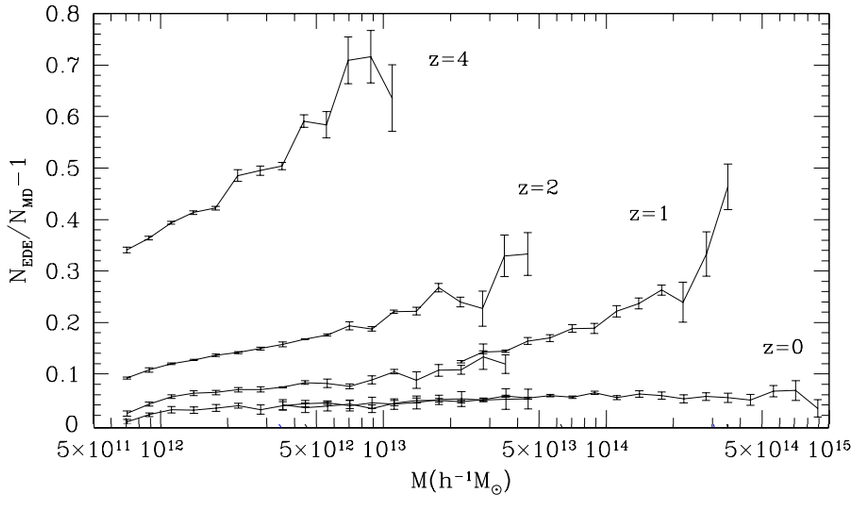

Figure 2: Increase of halo number densities as a function of halo mass at the same redshifts for ΛCDM+EDE compared with ΛCDM with the MultiDark-Planck parameters. Simulations were run using the GLAM Particle Mesh code (Klypin & Prada 2018).

Joel Primack RECENT PhD STUDENTS

Rachel Somerville (PhD 1997) Jerusalem, Cambridge (postdoc) –Michigan (Asst. Prof.) – MPI Astronomy Heidelberg (Professor) – STScI/Johns Hopkins – Rutgers (Professor) — CCA NYC
Michael Gross (PhD 1997) Goddard (postdoc) – UCSC (staff) – NASA Ames (staff)
James Bullock (PhD 1999) Ohio State – Harvard (Hubble Fellow) – UC Irvine (Prof., Dean)
Ari Maller (PhD 1999) Jerusalem – U Mass Amherst (postdoc) – CityTech CUNY (Assoc. Prof.)
Risa Wechsler (PhD 2001) Michigan – Chicago (Hubble Fellow) – Stanford U (Prof. & KIPAC Dir.)
T. J. Cox (PhD 2004) Harvard (postdoc, Keck Fellow) – Carnegie Observatories (postdoc) – Data Scientist at Apple, Cupertino
Patrik Jonsson (PhD 2004) UCSC (postdoc) – Harvard CfA (staff) – SpaceX senior programmer
Brandon Allgood (PhD 2005) – Numerate, Inc. (co-founder)
Matt Covington (PhD 2008) – analytic understanding of galaxy mergers, semi-analytic models of galaxy formation – U Minn (postdoc) – U Arkansas (Assoc. Prof.)
Greg Novak (PhD 2008) – running and comparing galaxy merger simulations with observations – Princeton (postdoc) – Inst Astrophysique Paris (postdoc) – Data Scientist at StichFix
Christy Pierce (PhD 2009) – AGN in galaxy mergers – Georgia Tech (postdoc) – teaching
Rudy Gilmore (PhD 2009) – WIMP properties and annihilation; extragalactic background light and gamma ray absorption – SISSA, Trieste, Italy (postdoc), Data Scientist at TrueCar, L.A.
Alberto Dominguez (PhD 2011) – UCR, Clemson (postdoc), Univ of Madrid (faculty)
Lauren Porter (PhD 2013) – semi-analytic predictions vs. observations, Data Scientist at Facebook
Chris Moody – analysis of high-resolution galaxy simulations: galaxy morphology transformations (PhD 2014) – Data Scientist at Square, then StichFix, San Francisco
Christoph Lee – galaxy-halo connection and deep learning for galaxy morphology (PhD 2019)

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I would welcome additional grad students