# A new study reveals potential inconsistencies in the current standard cosmological paradigm

*New insights from measurements of the Universe's expansion history by the Dark Energy Survey give hints of potential inconsistencies in the standard model of cosmology. If these findings are confirmed, this result can shake the foundations of physics.*

Decades of cosmological research have led to the development of a standard cosmological model known as ΛCDM. This model has had great success in describing the observed properties of the large-scale Universe, but has some striking implications. Around 95% of the Universe's content is formed by exotic materials that have never been produced in a laboratory, and whose physical nature is still unknown. These are dark matter, which amounts for 25% of the cosmos' content and corresponds to the CDM (for Cold Dark Matter) of the theory name, and dark energy, which amounts for almost 70% and corresponds to the Λ of the theory name. Only the remaining 5% is the ordinary matter that forms us and our surroundings.

In this standard model of cosmology the dark energy is the cosmological constant, which can be interpreted as describing the energy of empty space, and whose effective energy density remains constant along the time evolution of the Universe. However, a new result could be adding indications of a time-changing dark energy. These new observations come from the Dark Energy Survey (DES), a large international project designed to study dark energy. They concur with previous results from other cosmological observations, showing that these hints persist even in different galaxy surveys.

## The Cosmological Constant

In 1998, two groups of scientists discovered that the expansion of the Universe is speeding up with time. This acceleration was a huge surprise because according to our theory of gravity, Einstein's general relativity, the presence of matter in the Universe should slow down its expansion, and matter density should be diluted as space expands. Cosmic acceleration implies that the Universe contains something with very different properties, which we call dark energy. The cosmological constant, Λ, is the simplest explanation of this behavior.

The ΛCDM model has been established as the standard model of cosmology by many observations performed since 1998. However, the scientific projects studying the Universe have been growing in accuracy and sensitivity and current cosmological observations are precision science. This situation allows for very stringent tests of ΛCDM.

## The Dark Energy Survey

As its name denotes, DES is a large scientific project specially designed to study dark energy. It is an international collaboration of more than 400 scientists from 7 countries, led by Fermilab, a national laboratory of the US Department of Energy. The project uses four different and complementary methods to study the dark energy: cosmological distances measured with supernovae Ia, the number of galaxy clusters, the clustering of galaxies and weak gravitational lensing (a more detailed description can be found at: https://www.darkenergysurvey.org/the-des-project/science).

These are two types of cosmological probes. Distance measurements made using supernovae and a feature in the statistical distribution of galaxies known as the baryon acoustic oscillation (BAO) scale measure the expansion history of the Universe, while galaxy clusters, weak lensing, and other properties of galaxy clustering measure how the large structures of the Universe (galaxies, galaxy clusters, etc.) have grown due to the effect of gravity. In addition, these methods can be combined to obtain a stronger statistical power and a better control of observations.

In order to be able to use all these techniques in the same telescope and with the same instrument, DES built the Dark Energy Camera (DECam). With 500 Megapixels, it is one of the largest and most sensitive cameras in the world. It is installed at the 4-meter V. M. Blanco telescope in the Cerro Tololo Interamerican Observatory (CTIO) in Chile, and operated by the National Science Foundation. DES has mapped one eighth of the sky to an unprecedented depth. The project took images in five colors from 2013 to 2019 and currently is in the final phase of the scientific analysis of those images.

## The mysterious dark energy could be changing

DES has very recently published its final measurement of the expansion history of the Universe, a combination of two of its major probes, the BAO scale and the distances obtained using supernovae Ia. This is a major milestone both for DES and for galaxy survey cosmology.

The BAO scale refers to a special length scale in the Universe: the distance that sound waves were able to travel in the early Universe. This special size is what cosmologists call a standard ruler. In this case, it is 500 millions light years long. Such a large ruler allows us to measure cosmological distances by comparing how its apparent size changes as we look at galaxies that are further away. DES analyzed 16 million galaxies to measure this BAO scale.

“If we compute the distance between all possible galaxy pairs, the number of pairs separated by the BAO scale is larger, providing the signal for the standard ruler”, comments Santiago Avila, a Ramón y Cajal fellow at CIEMAT (Spain), responsible for the BAO analysis in DES. “However, the measured BAO scale in data is 4% smaller than the size predicted by ΛCDM”.

Supernovae Ia are huge stellar explosions with a property that makes them special: their brightness can be calibrated to make all of them equal, turning them into standard candles. In this way, they become excellent cosmic distance indicators. Since all of them have equal inherent brightness, if we observe fainter supernovae then they are further away, while brighter supernovae are closer to us. "DES has compiled the largest and deepest supernovae Ia set to date" says Maria Vincenzi, from Oxford University, responsible for the supernovae program in DES. "Using this sample, we have been able to measure cosmic distances and directly trace the expansion of our Universe further than any previous supernova surveys and with significantly higher accuracy". This analysis provided a measurement of cosmic distances that is independent of, and complementary to, that obtained with the BAO scale.

By combining both determinations of distances with the cosmic microwave background and other properties of the early Universe, DES can obtain the physical properties the dark energy must have to explain them. The result is startling. Data seem to favor a time-evolving dark energy.

“This result is intriguing, because it suggests that we may be seeing indications of a new physics beyond the standard model of cosmology”, says Juan Mena, a postdoctoral researcher at the Subatomic Physics and Cosmology Laboratory in Grenoble (France), one of the responsibles of the combined analysis. “If further data supports these findings, we could be on the brink of a revolution in our understanding of the Universe.”

These results are not significant enough yet, and thus a discovery cannot be claimed. Later this year, we look forward to a full combination with the remaining probes DES uses to study dark energy, which are more sensitive to the growth of large-scale structure in the Universe. These will provide both better constraints on dark energy and crucial cross-checks that the emerging picture is self-consistent across these probes. In addition, similar results are being observed in other large cosmological projects like DESI (Dark Energy Spectroscopic Instrument). This situation puts the scientific community on alert. If dark energy changes with time, it cannot be the cosmological constant. It should be a new kind of matter-energy or a new physical phenomenon. It could be a new quantum field, different from all that are known, that fills the space and is not in our current quantum theory of matter or it could be the first indication for the need of an extension of the general relativity theory. Such a discovery would shake fundamental physics and provide a deeper understanding of the Universe.

“These results are a culmination of years of collaborative work exploring what cosmological distance measurements from the completed DES can tell us about the expanding Universe”, comments Jessie Muir, of the University of Cincinnati, who has collaborated in the combined analysis. “There is clearly more to learn and work to do. It will be exciting to watch how our understanding of these results evolves as we further explore what DES data can tell us about physics and study them alongside other measurements of the large-scale Universe.”

***Link to scientific paper:*** *https://arxiv.org/abs/2503.06712*

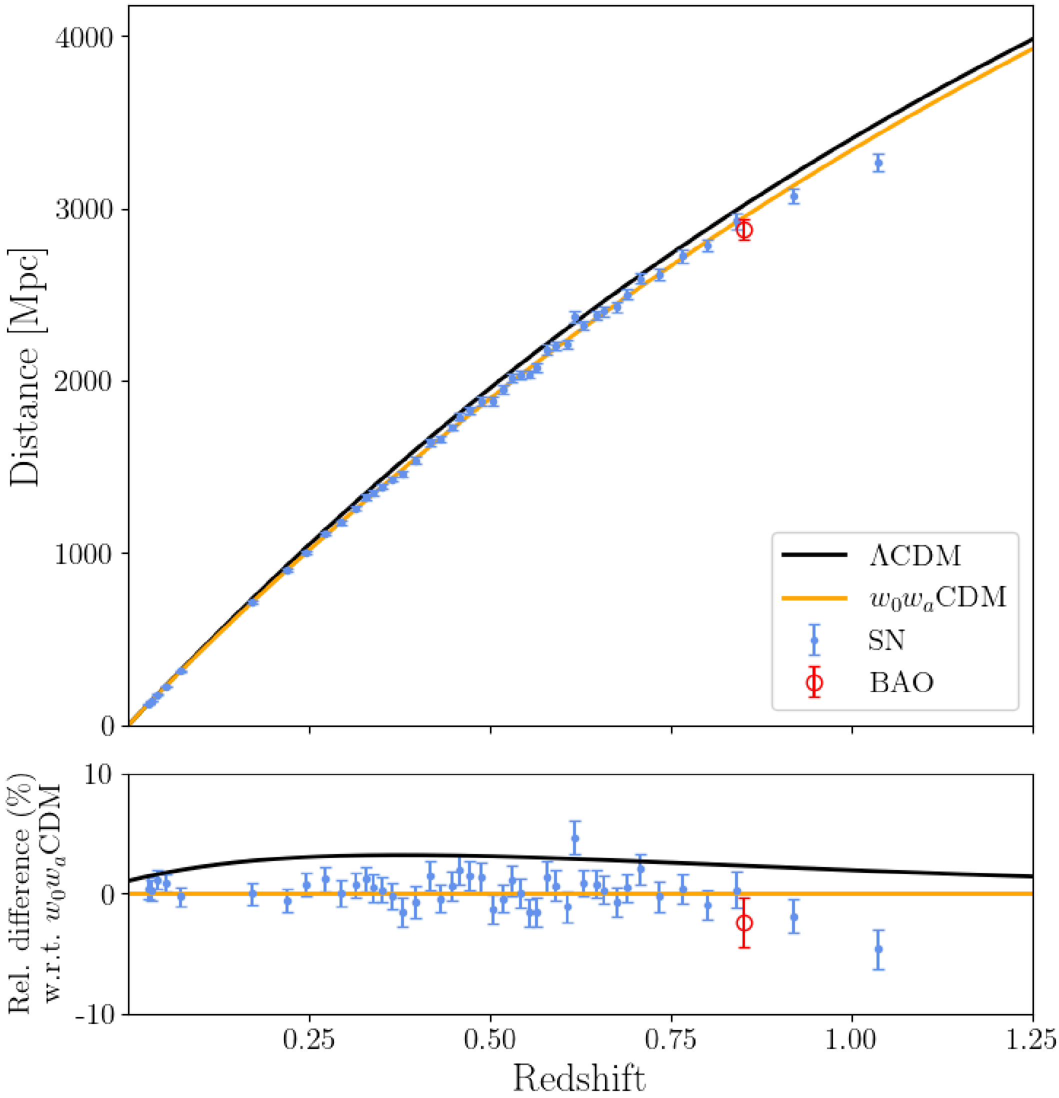
*Funding for the DES Projects has been provided by the U.S. Department of Energy, the U.S. National Science Foundation, the Ministry of Science and Education of Spain, the Science and Technology Facilities Council of the United Kingdom, the Higher Education Funding Council for England, the National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign, the Kavli Institute of Cosmological Physics at the University of Chicago, Funding Authority for Funding and Projects in Brazil, Carlos Chagas Filho Foundation for Research Support of the State of Rio de Janeiro, Brazilian National Council for Scientific and Technological Development and the Ministry of Science and Technology, the German Research Foundation and the collaborating institutions in the Dark Energy Survey,* *The U.S. National Science Foundation's National Optical-Infrared Astronomy Research Laboratory (NOIRLab) operates the Cerro Tololo Inter-American Observatory (CTIO) and Vera C. Rubin Observatory (operated in cooperation with the U.S. Department of Energy's SLAC National Accelerator Laboratory). The research community is honored to have the opportunity to conduct research on Cerro Tololo and Cerro Pachón in Chile. We recognize and acknowledge the very significant cultural role and reverence that these sites have to the local communities in Chile.*

*Based in part on data acquired at the Anglo-Australian Telescope for the Dark Energy Survey by OzDES. We acknowledge the traditional custodians of the land on which the AAT stands, the Gamilaraay people, and pay our respects to elders past and present.*

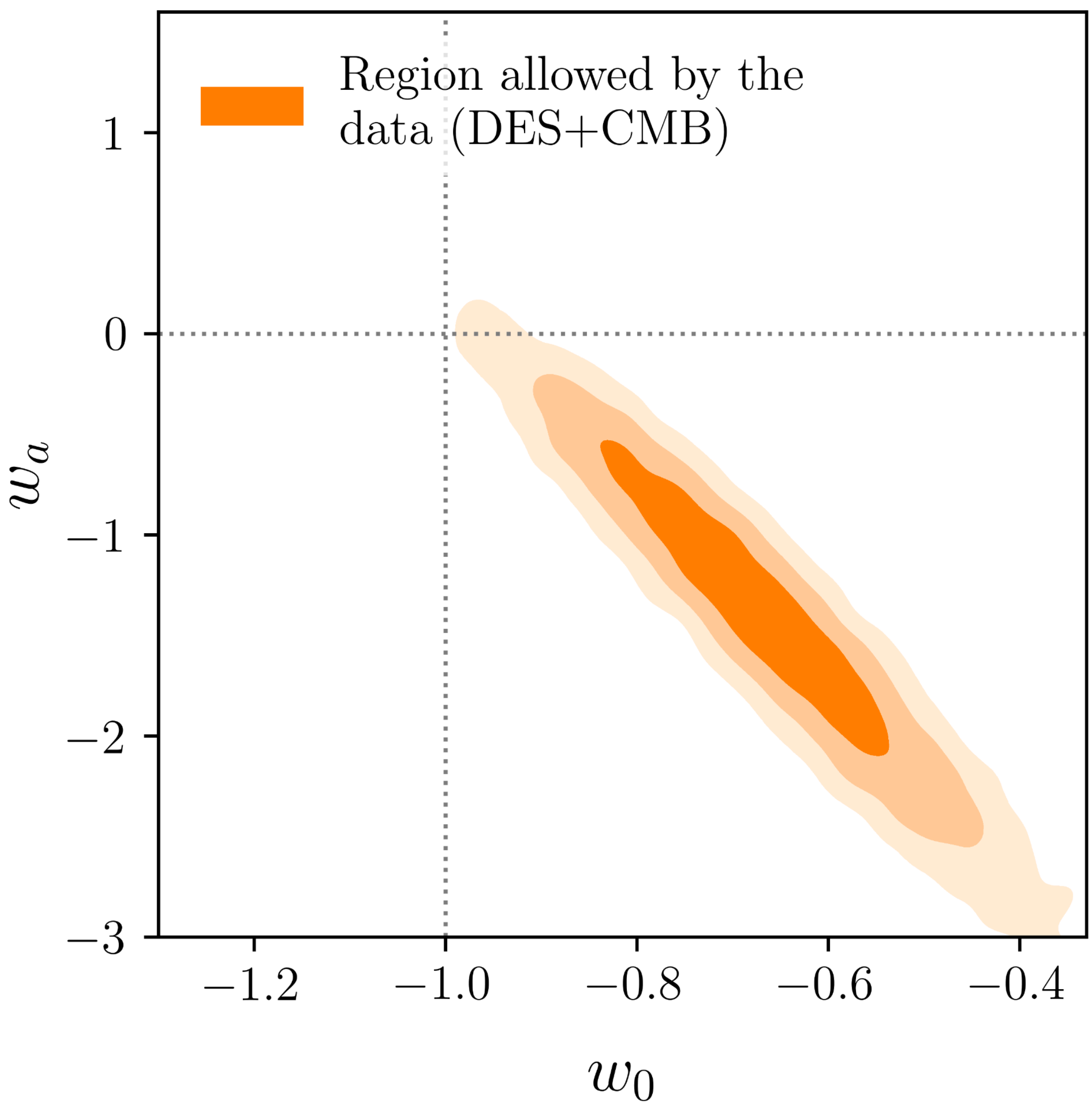
*Fermilab is America's premier national laboratory for particle physics and accelerator research. A U.S. Department of Energy Office of Science laboratory, Fermilab is located near Chicago, Illinois, and operated under contract by the Fermi Research Alliance LLC. Visit Fermilab's website at www.fnal.gov and follow us on Twitter at @Fermilab.*

*The DOE Office of Science is the single largest supporter of basic research in the physical sciences in the United States and is working to address some of the most pressing challenges of our time. For more information, please visit science.energy.gov*

**Graphics:**




*Measurements of distances from DES using supernovae Ia (blue) and BAO (red). Data are compared with the predictions of a universe where the dark energy is the cosmological constant (black line) and with a universe where the dark energy changes with time (orange line). Data follow the orange line. The top panel is the full distance, the bottom panel is a zoom, showing relative differences with respect to the time varying dark energy.*
*Credits: Dark Energy Survey*




*Determination of the parameters of the dark energy form DES and the Cosmic Microwave Background (CMB). A cosmological constant should be in the intersection of the vertical and horizontal lines (-1,0), However, data favor values inside the orange region, where dark energy changes with time.*
*Credits: Dark Energy Survey.*

*Image of the DES deep fields where supernovae are searched. The image is full of galaxies. Nearly every single object in this image is a galaxy. Some exceptions include a few foreground stars in the Milky Way and a few asteroids.*
*Credits: Dark Energy Survey/DOE/FNAL/DECam/CTIO/NOIRLab/NSF/AURA. Thanks: T. A. Rector (University of Alaska/NOIRLab), J. Miller, M. Zamani y D. de Martin (NSF NOIRLab)*

*Image of the Cerro Tololo Inter-American Observatory (CTIO) in Chile. In the foreground, with the dome opened, the V. M. Blanco telescope. Inside the dome the telescope and the DECam camera can be seen. The DES data were recorded in this telescope and with this camera.*
*Credits: CTIO/NOIRLab/NSF/AURA/T. Matsopoulos.*