New evidence suggests dark energy is weakening!

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Monday 28 July 2025 at 11:00 A.M.

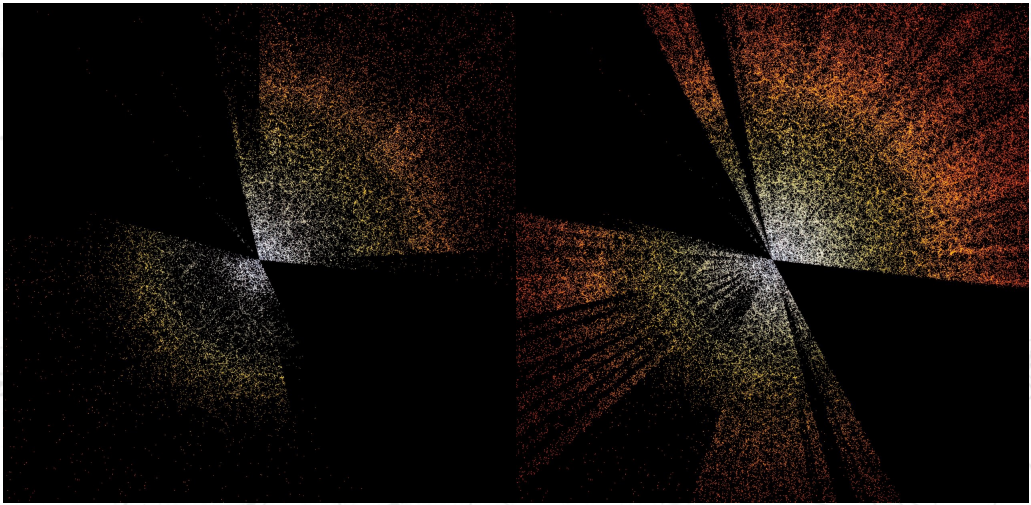
arXiv: 2503.14738

Astrophysics - Cosmology and Nongalactic Astrophysics

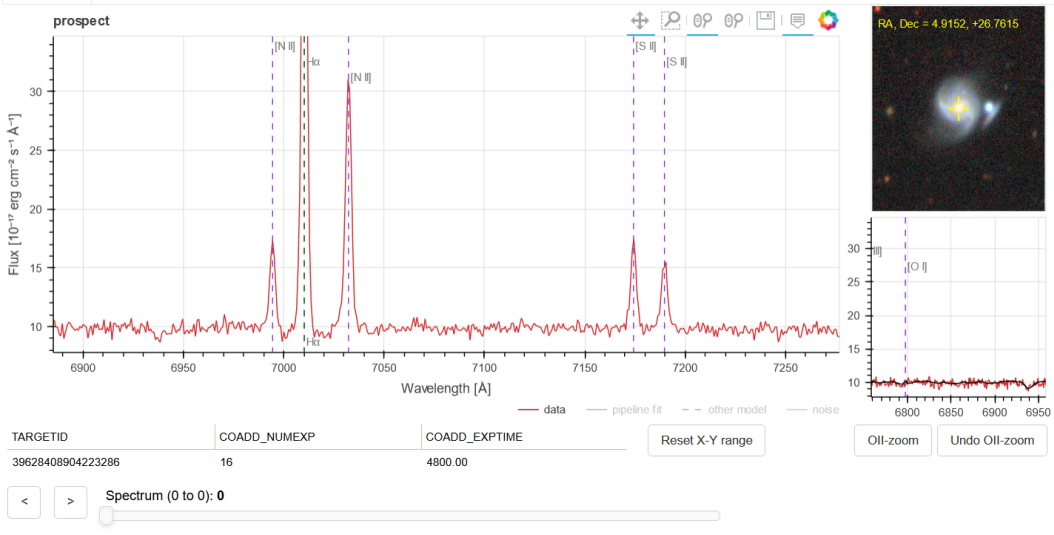
The Dark Energy Spectroscopic Instrument (DESI). DESI installed on the Nicholas U. Mayall 4-meter Telescope at Kitt Peak National Observatory.

DESI is mounted on Kitt Peak National Observatory's Nicholas U. Mayall 4-meter telescope.

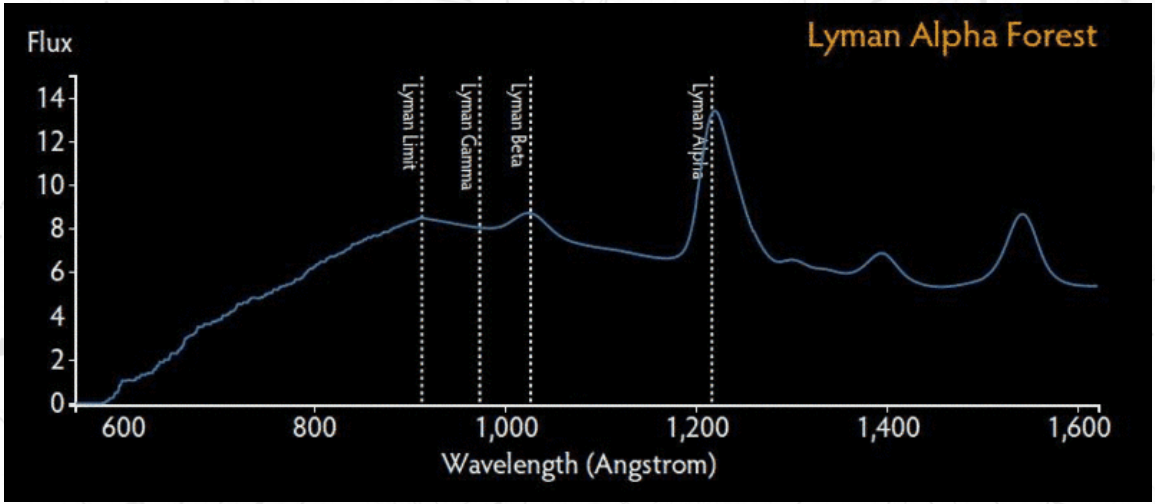
An artistic celebration of the Dark Energy Spectroscopic Instrument (DESI) year-one data, showing a slice of the larger 3D map that DESI is constructing during its five-year survey.



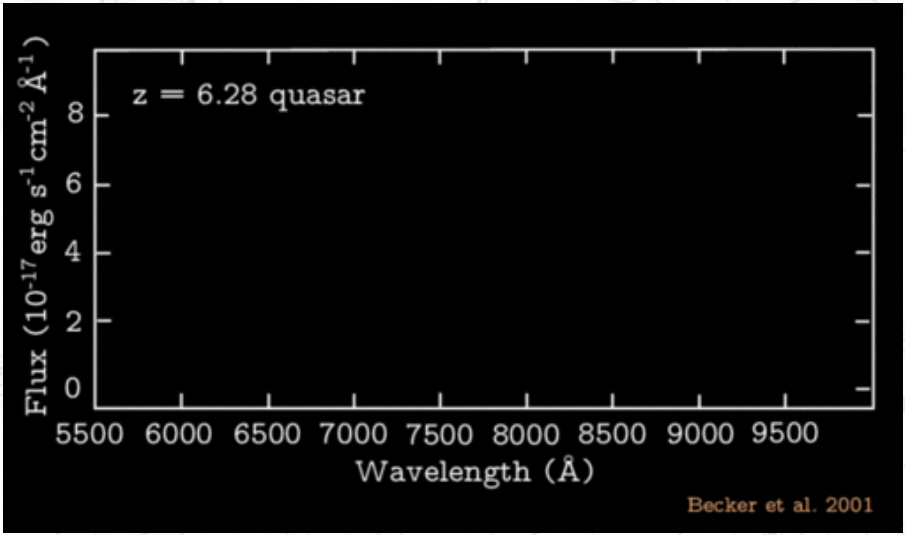
Comparison of the Sloan survey at left, consisting of around 4 million galaxies and quasars taken from 2000 to 2020, and the DESI survey at right, consisting of around 7.5 million during its first 7 months starting in 2021 and expected to be completed by 2026 with 35 million.



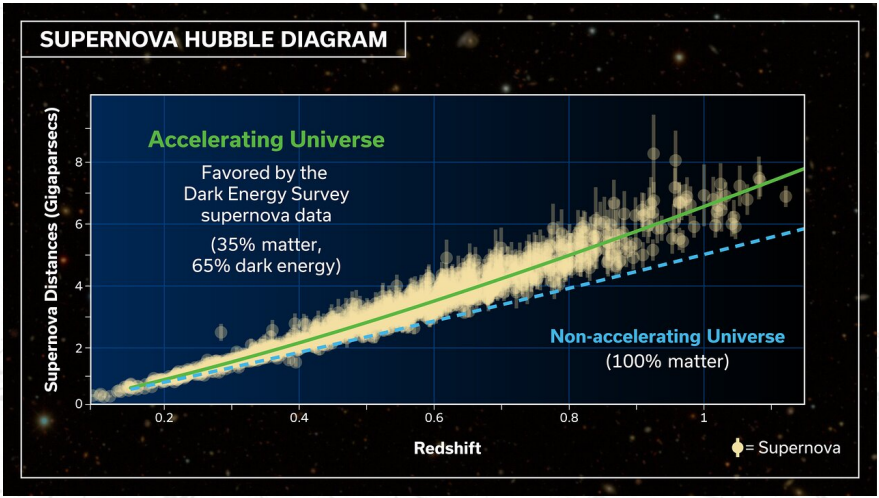
Example spectrum taken by DESI for the Early Data Release: the image shows the spectrum of the galaxy LEDA 1787534.



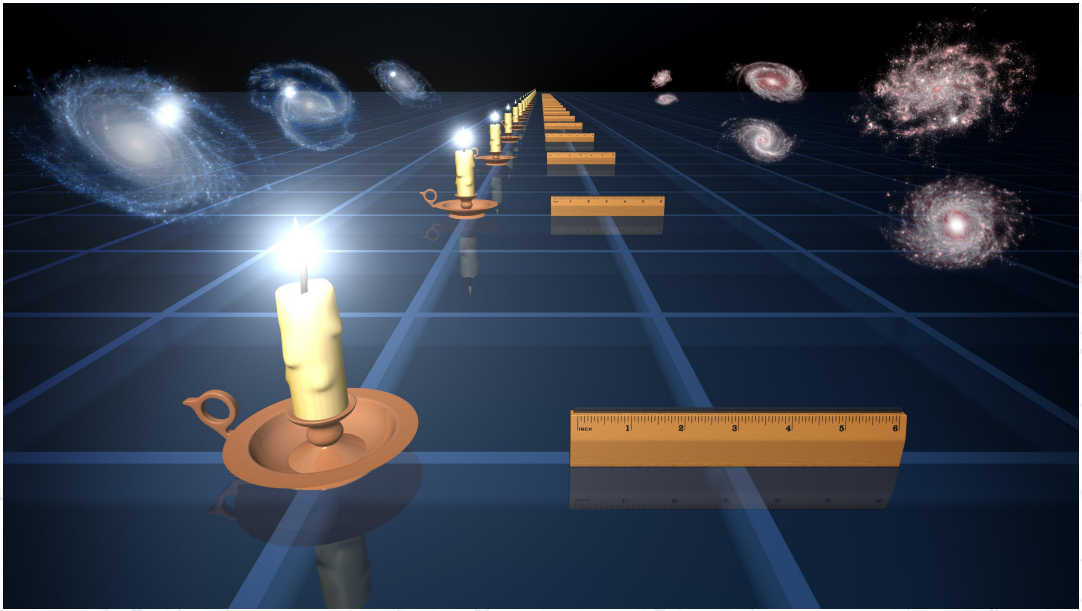
A quasar spectrum with Lyman absorbers continuously redshifted due to cosmic expansion, resulting in a "forest" of lines.



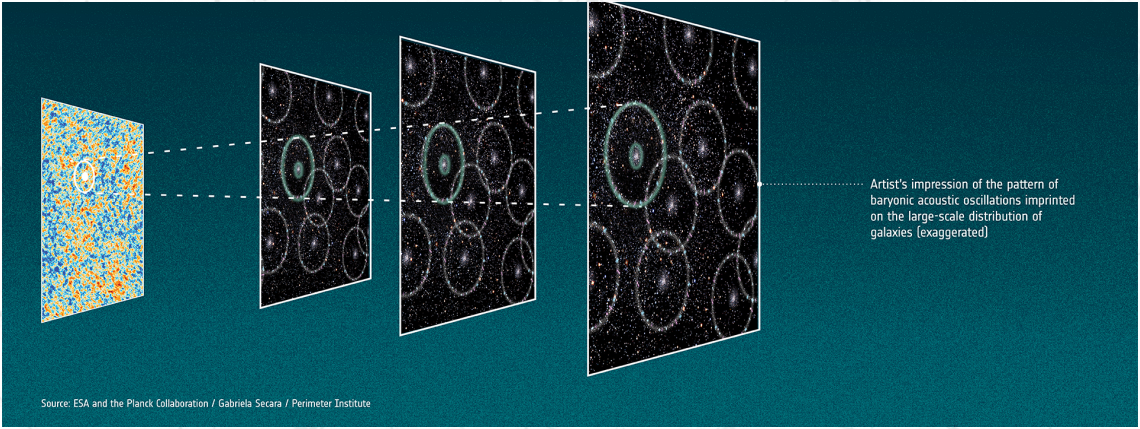
No zero flux troughs were created by different Lyman absorbers in the spectrum of the first confirmed observation of the effect.



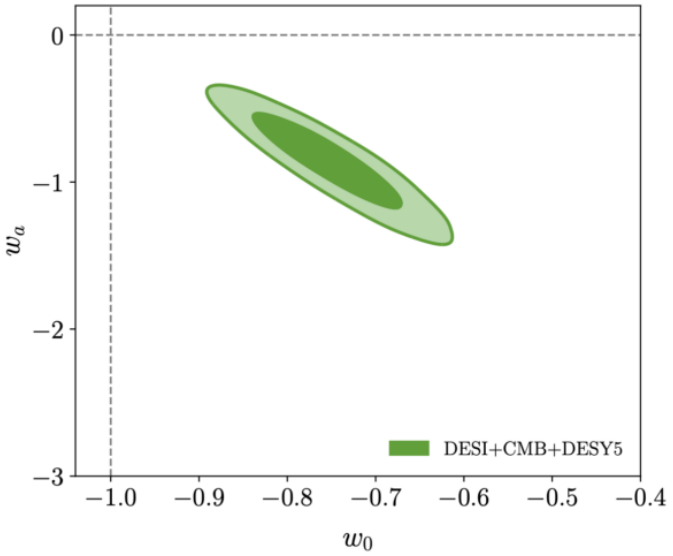
The history of the expanding universe can be traced by comparing recessional velocities (redshifts) to distances calculated for each supernova. The Dark Energy Survey results demonstrate that the expansion has accelerated throughout cosmic time, which is a characteristic of dark energy.



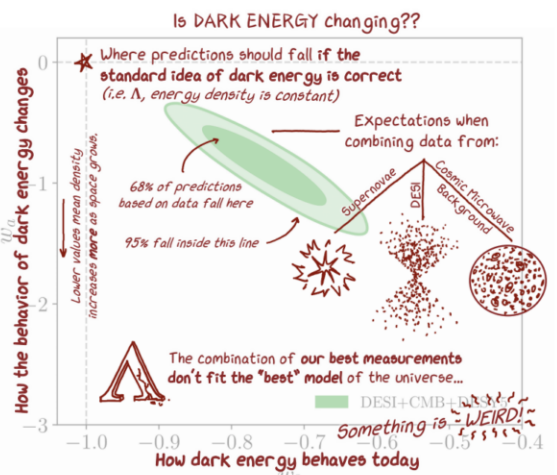
The standard candle and ruler for measuring the universe.


Artist's impression of the pattern of baryonic acoustic oscillations imprinted on the large-scale distribution of galaxies (exaggerated)
Source: ESA and the Planck Collaboration / Gabriela Secara / Perimeter Institute

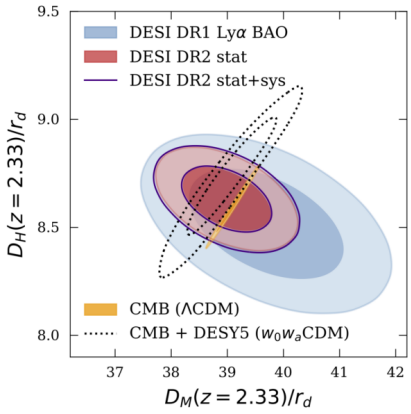
BAO Scale.



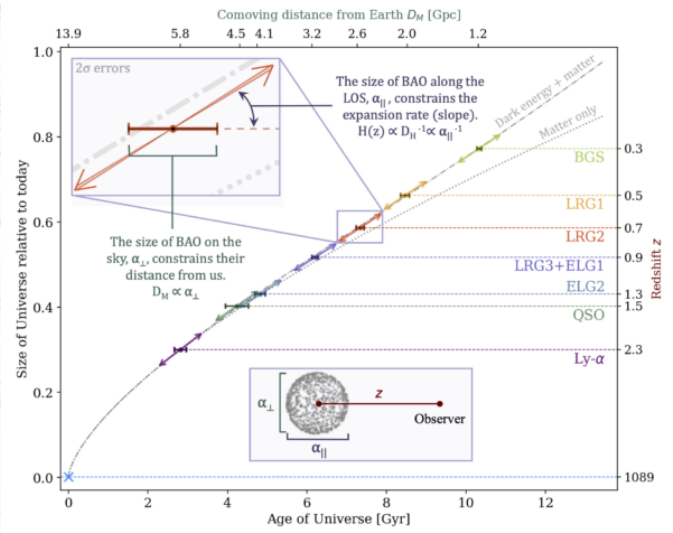
One of many contours addressed in the DR2 BAO cosmological study report, demonstrating the restrictions on parameters of growing dark energy.



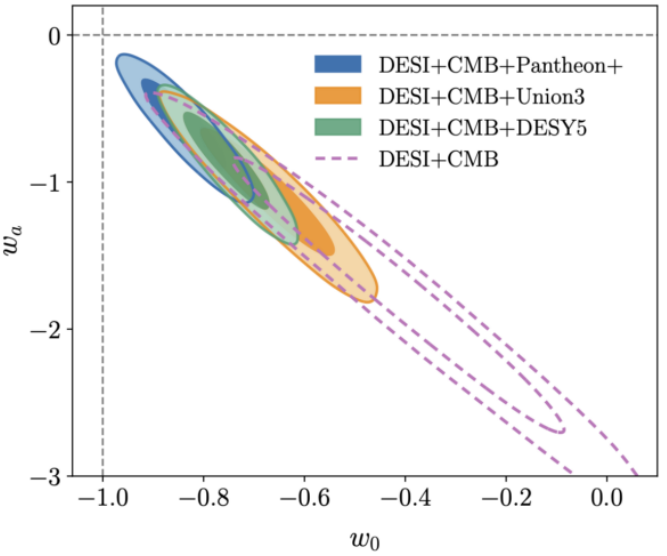
Let's delve into the significance of the aforementioned statistic for a wide-ranging audience. The overall density of matter decreases as the universe expands. Dark energy, however, is distinct! The "behavior" of dark energy, or how its density varies with space expansion, is seen in this graphic.



This graphic depicts the Lyman-alpha BAO measurement from DR2 with statistical-only uncertainties (red contour) and statistical+systematic uncertainties (solid indigo contour). Previous DESI DR1 results are shown (light-blue contour), as well as constraints inferred from Planck CMB data assuming ΛCDM (orange contour). Finally, the combined Planck CMB and DES Year 5 supernovae data assuming w_0w_aCDM is depicted (dotted black contour).



The figure depicts how DESI DR2 BAO data constrain the universe's expansion history. The measurements from the seven tracer samples are displayed as colored points with error bars.

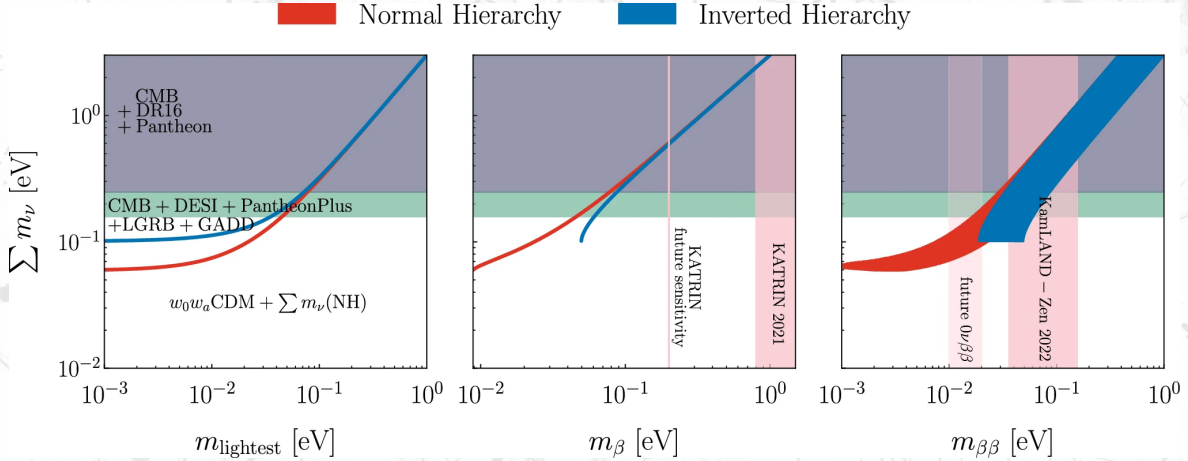


Constraints on the dark energy equation of state derived by fitting the $w_0 w_a$CDM model to DESI DR2 using CMB alone and CMB with three supernovae datasets.

Constraints on Neutrino Mass

$\sum m_\nu < 0.0642$ eV (95%) for the ΛCDM model, and $\sum m_\nu < 0.163$ eV (95%) for the $w_0 w_a$CDM model, based on $0.1 < z < 4.2$ Lyman-α forest and galaxies from Data Release 2 (DR2). Accounting for neutrino oscillation limitations, the normal mass ordering was preferred, with an upper bound of $m_l < 0.023$ eV (95%) on the lightest neutrino mass.

Constraints on Neutrino Physics from DESI DR2 BAO and DR1 Full Shape, W. Elbers et. al arXiv:2503.14744 Cosmology and Nongalactic Astrophysics (astro-ph.CO).


Normal Hierarchy
Inverted Hierarchy
CMB
+ DR16
+ Pantheon
CMB + DESI + PantheonPlus
+LGRB + GADD
$w_0w_a\mathrm{CDM} + \sum m_\nu(\mathrm{NH})$
$\sum m_\nu$ [eV]
m_{lightest} [eV]
KATRIN
future sensitivity
KATRIN 2021
m_β [eV]
future $0\nu\beta\beta$
KamLAND − Zen 2022
$m_{\beta\beta}$ [eV]

Results for neutrino masses from cosmology and particle physics experiments are compared. The left panel shows $\sum m_\nu$ as a function of the mass of the lightest neutrino $m_{\rm lightest}$. The purple and green regions indicate the $\sum m_\nu < 0.248\ \mathrm{eV}$ and $\sum m_\nu < 0.158\ \mathrm{eV}$ exclusion regions in the $w_0 w_a \mathrm{CDM} + \sum m_\nu\ (\mathrm{NH})$ model obtained by CMB+DR16+Pantheon and CMB+DESI+PantheonPlus+LGRB+GADD, respectively. Middle panel: $\sum m_\nu$ as a function of β minus decay effective mass m_β. The pink banded area represents the most recent KATRIN result $m_\beta < 0.8\ \mathrm{eV}$, and the pink line represents the KATRIN future sensitivity. $0.2\ \mathrm{eV}$. The right panel shows $\sum m_\nu$ as a function of neutrinoless double β-decay effective mass $m_{\beta\beta}$. The pink banded area shows the most recent results $m_{\beta\beta} < 0.036 - 0.156\ \mathrm{eV}$ from the KamLAND-Zen cooperation, while the light pink banded area shows future sensitivity $m_{\beta\beta} < 0.01 - 0.02\ \mathrm{eV}$.

Impacts of dark energy on weighing neutrinos after DESI BAO,
Guo-Hong Du, Peng-Ju Wu, Tian-Nuo Li and Xin Zhang,
Eur. Phys. J. C 85, 392 (2025).