New Light on Dark Energy: The Mystery Deepens

Dark Energy Survey Supernova (DES) Cosmology Final Results
Dark Energy Spectroscopic Instrument (DESI) Year 1 results

UC Louvain, October 2024
Tamara Davis, University of Queensland

The AAT and its siblings

AAT

2dF (OzDES)

Blanco

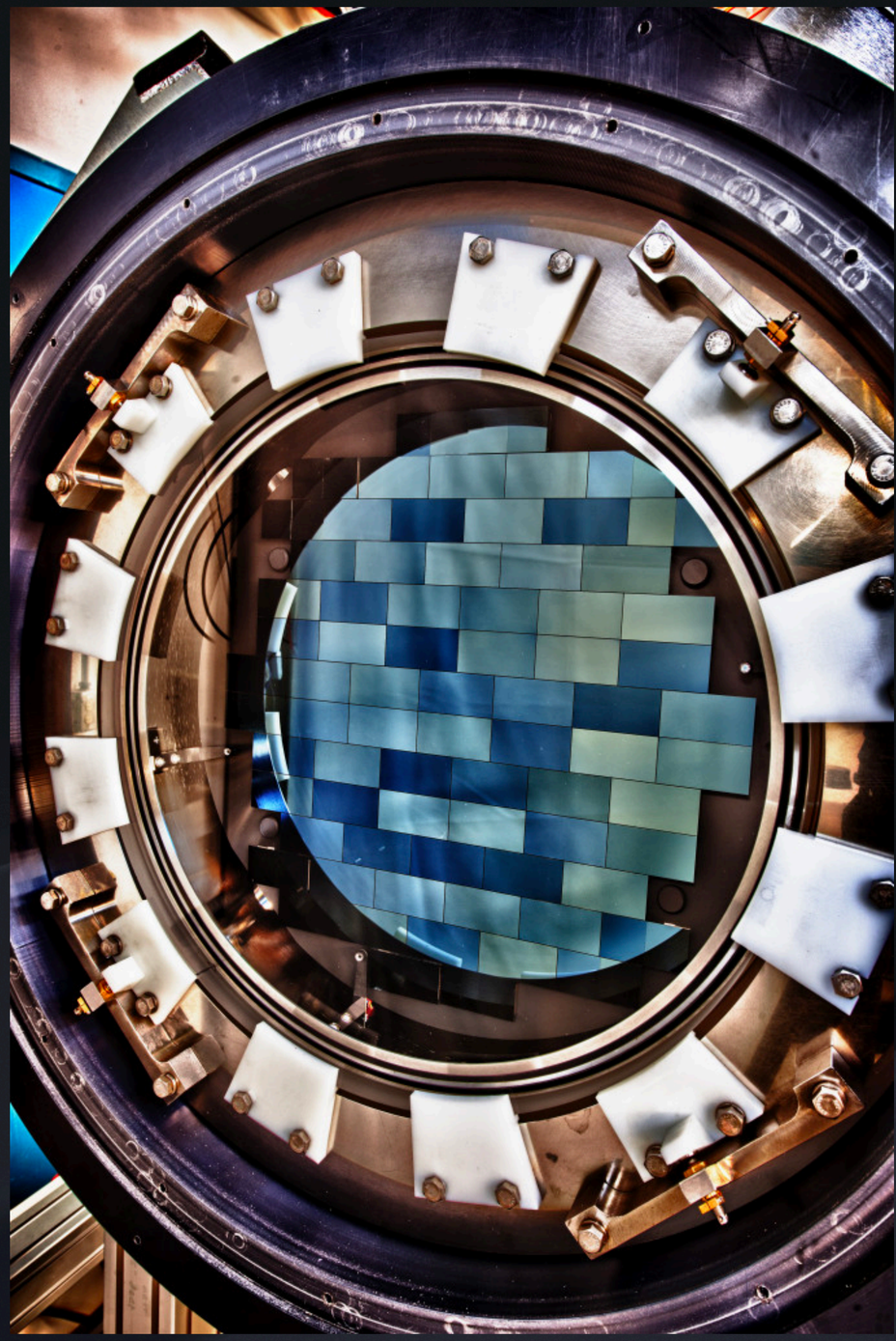
DECam (DES)

Mayall

DESI

The Dark Energy Survey

(DES)



The Dark Energy Survey

570 mega-pixels
10 years designing
6 years observing

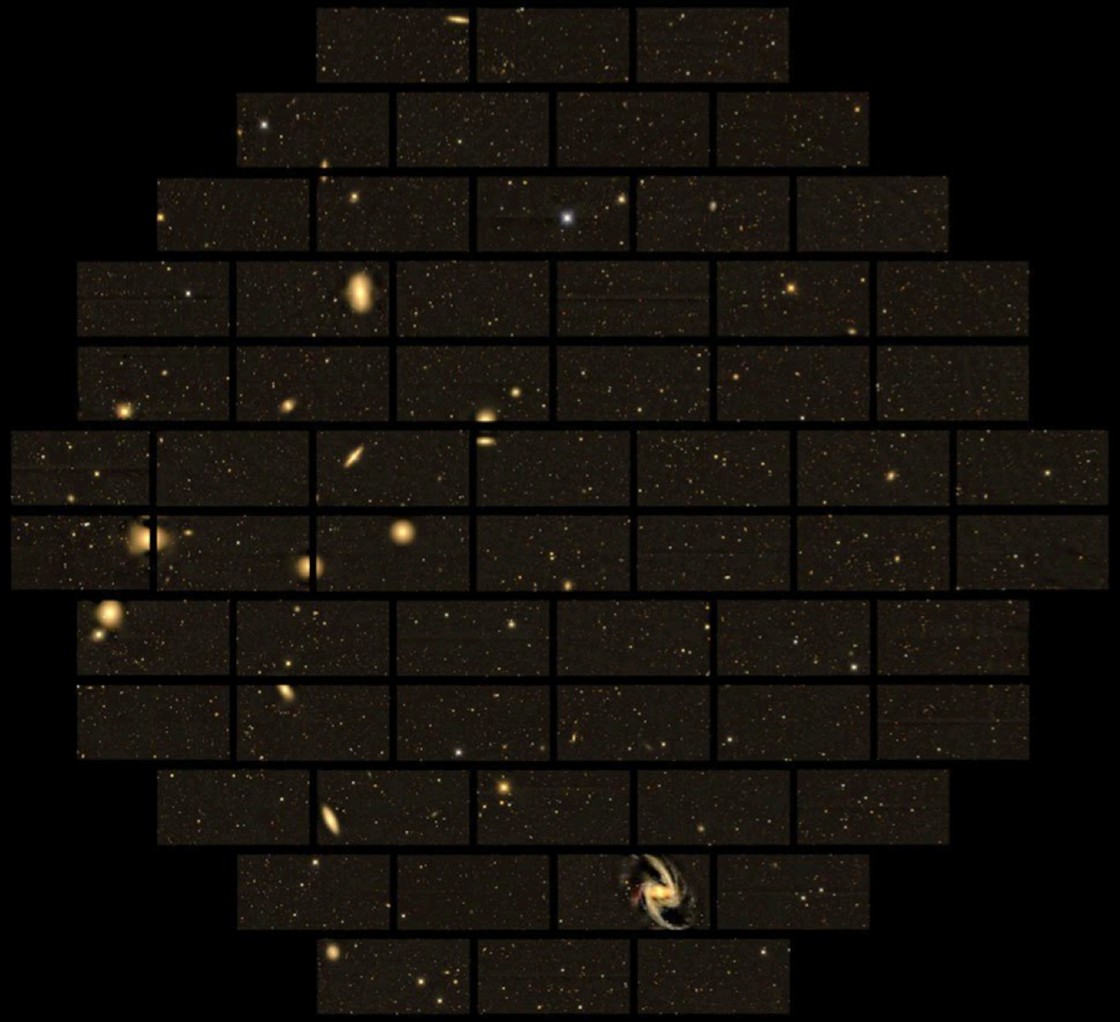
Approximately:
- 543 million galaxies
- 145 million stars
- 700,000 asteroids
- 10,000 supernovae

A 2dF night at the Anglo-Australian Telescope

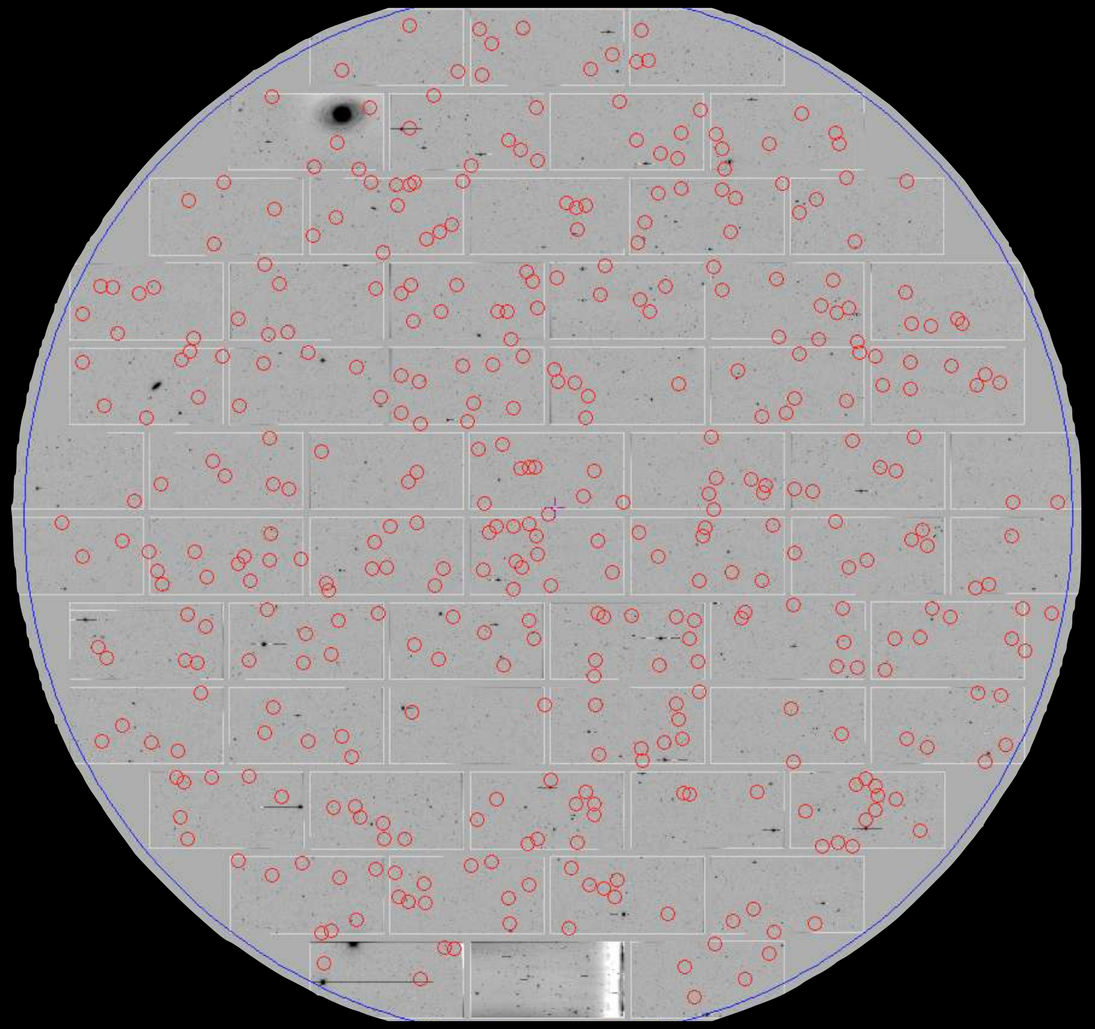
Australian Government

Department of Industry
Innovation, Science, Research
and Tertiary Education

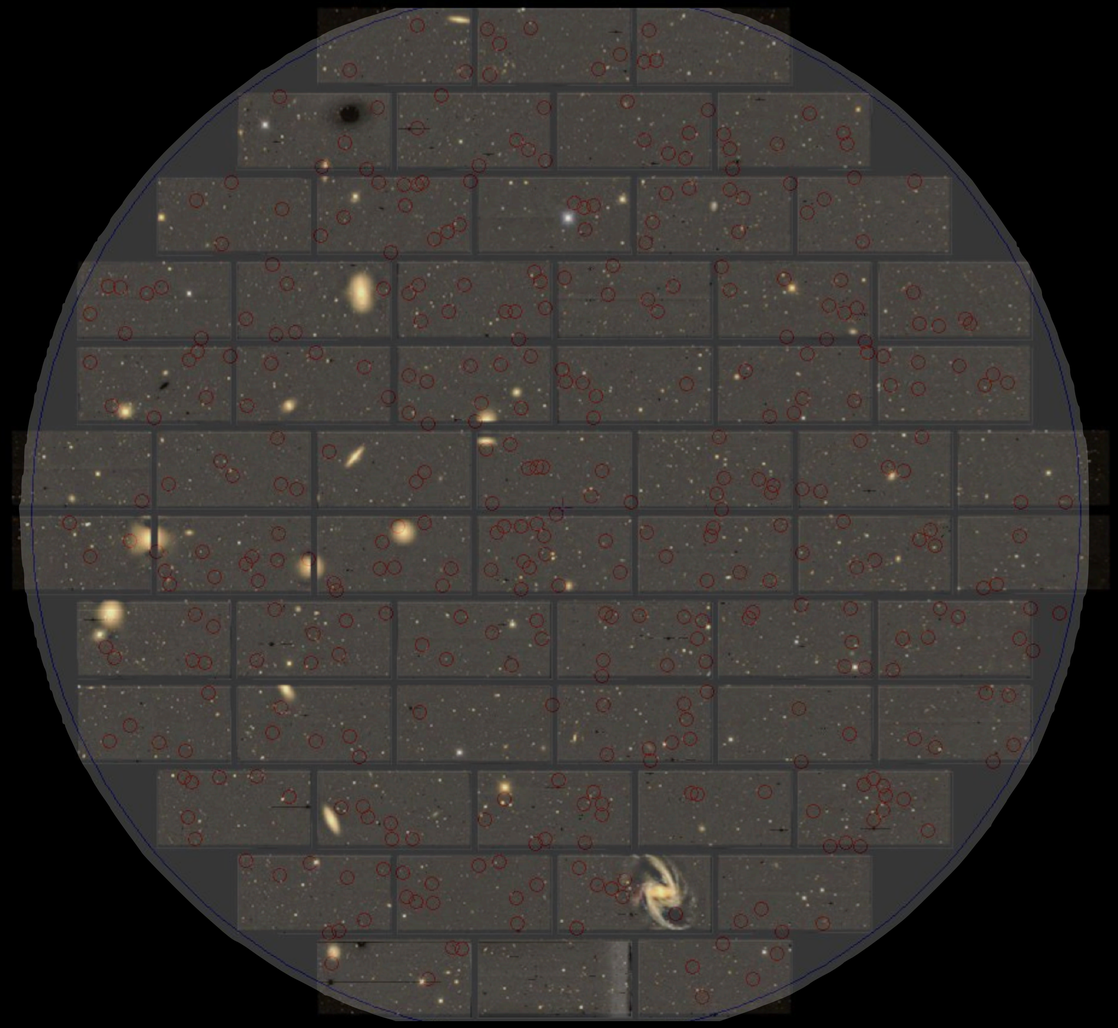
by Ángel López-Sánchez



DECam (DES)



2dF (OzDES)



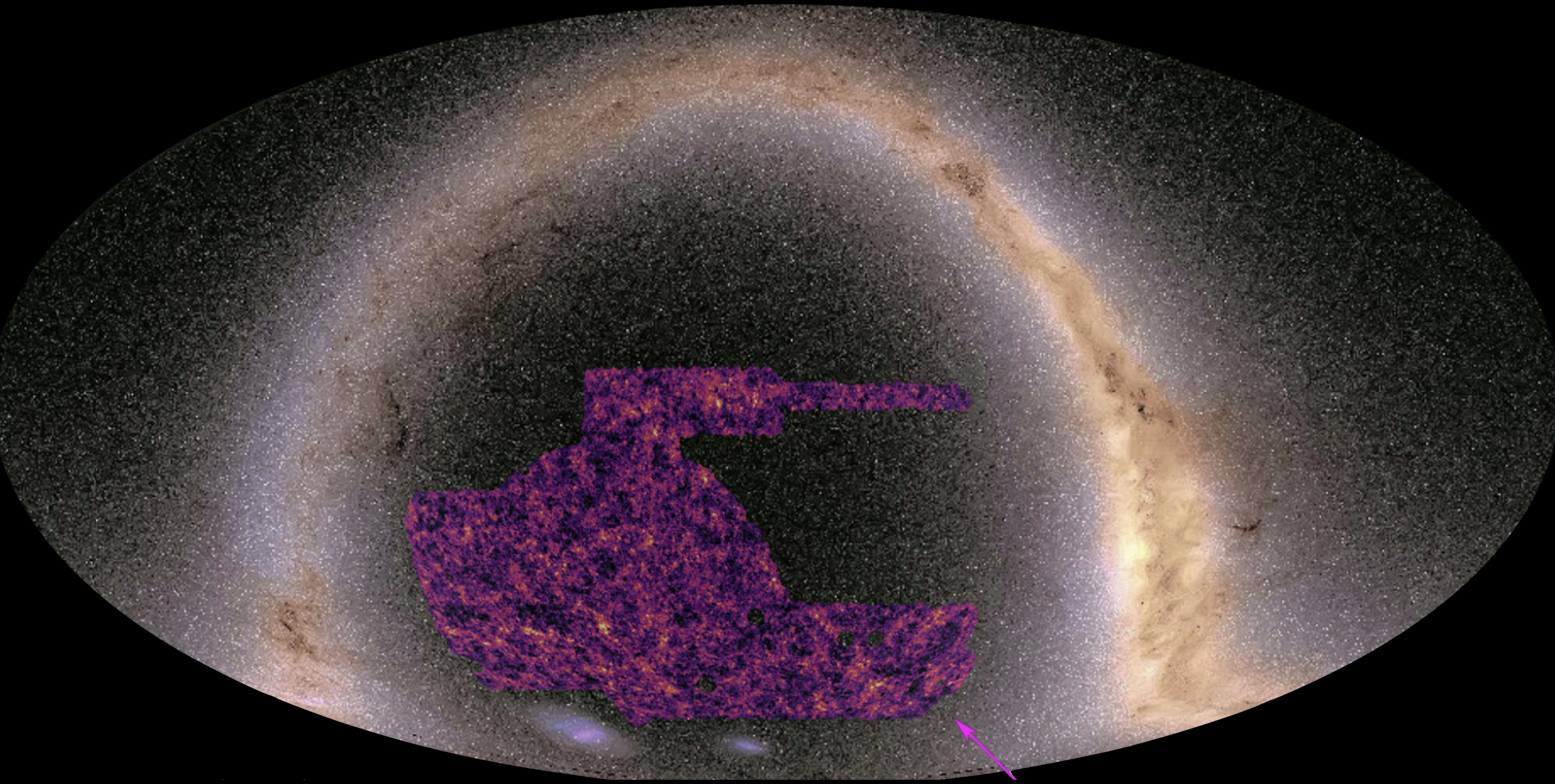
DECam (DES)

2dF (OzDES)

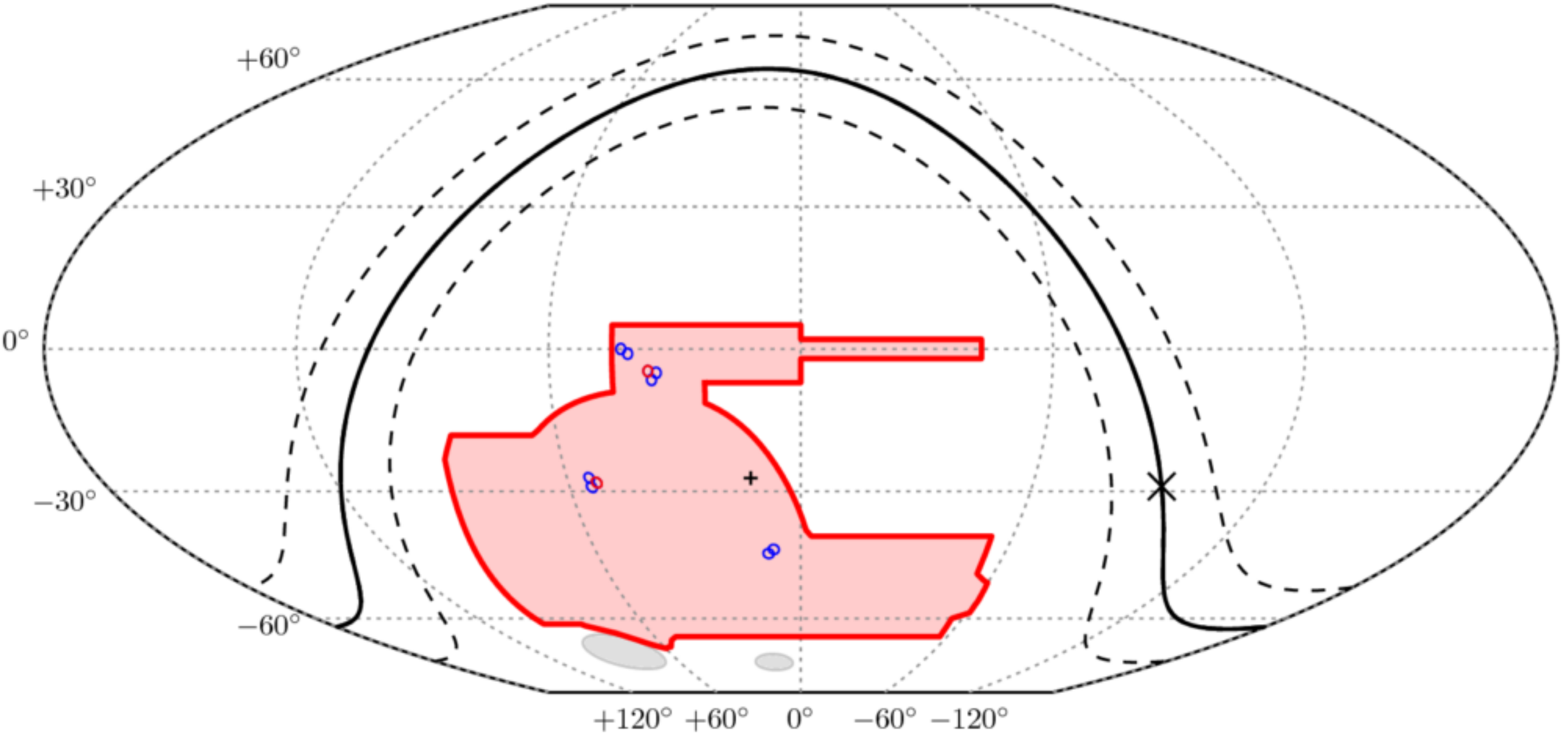
Chris Lidman

DES @ UQ


FORGAN SMITH
BUILDING
GREAT IS TRUTH
AND MIGHTY
ABOVE ALL THINGS.

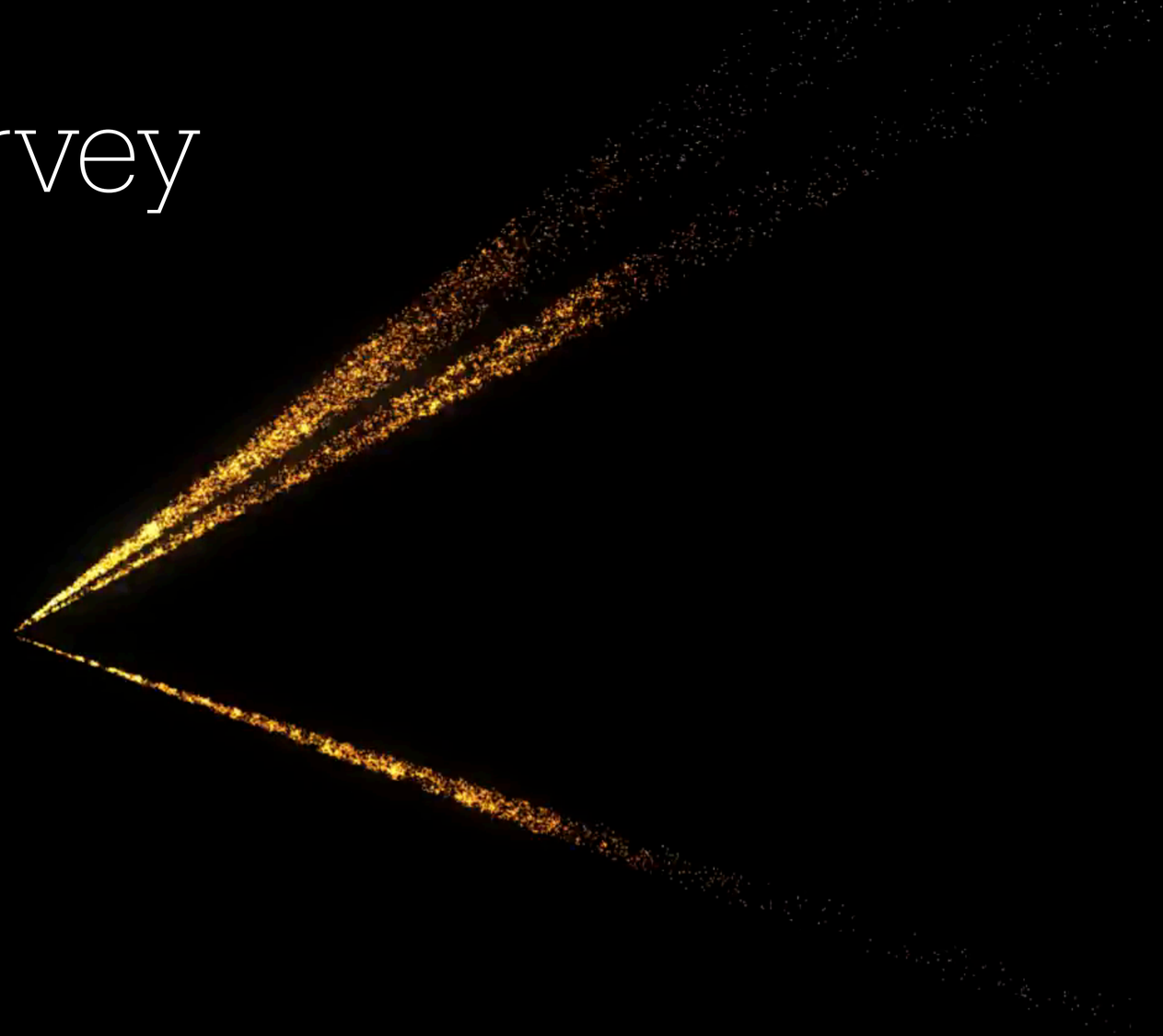


The Dark Energy Survey



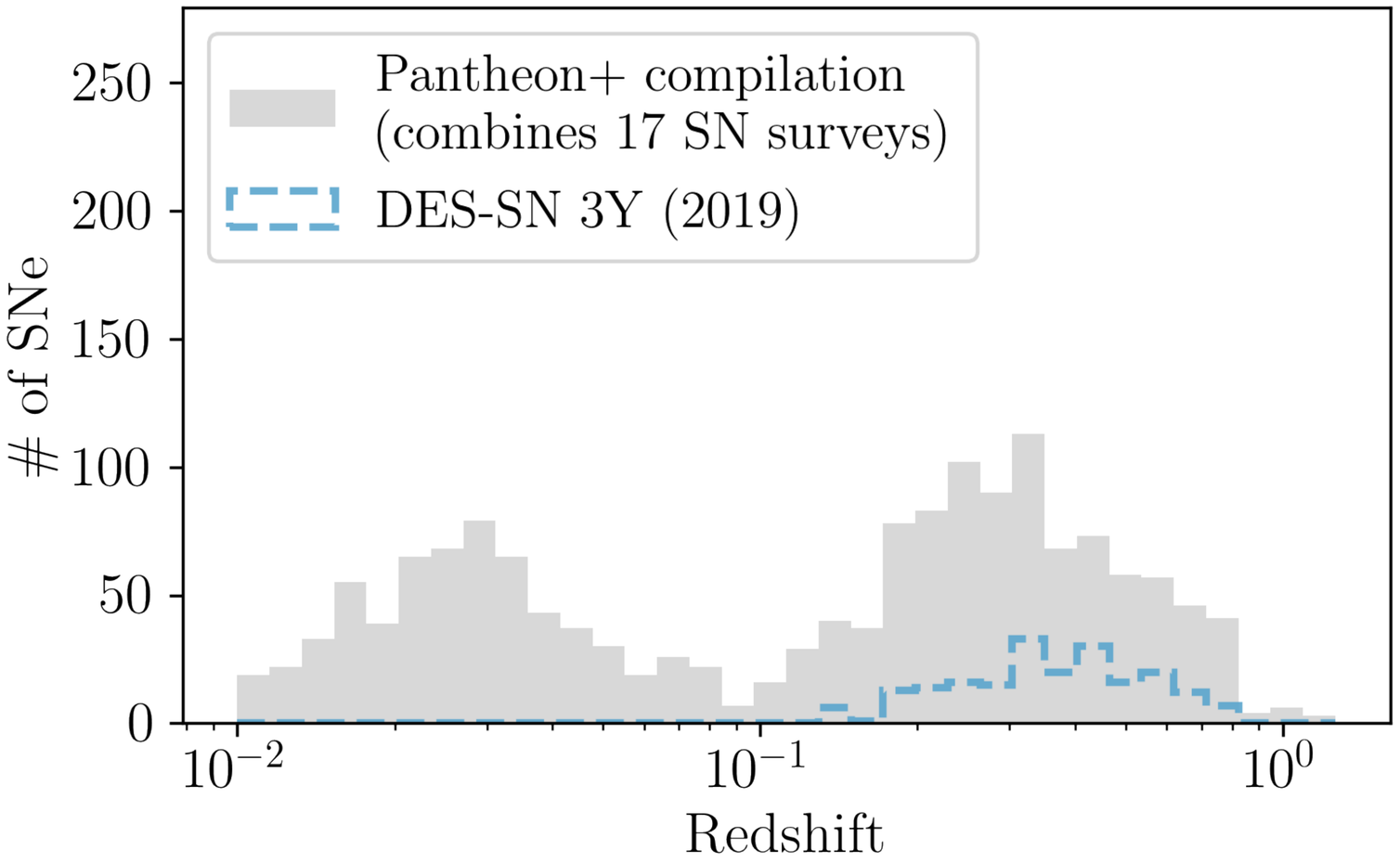
The Dark Energy Survey

(DES)



The DES Sample

The **largest** and **deepest** SN sample from a **single telescope** ever compiled



Pantheon+ and **Union** compilations
Brout et al. 2021
Rubin et al. 2024

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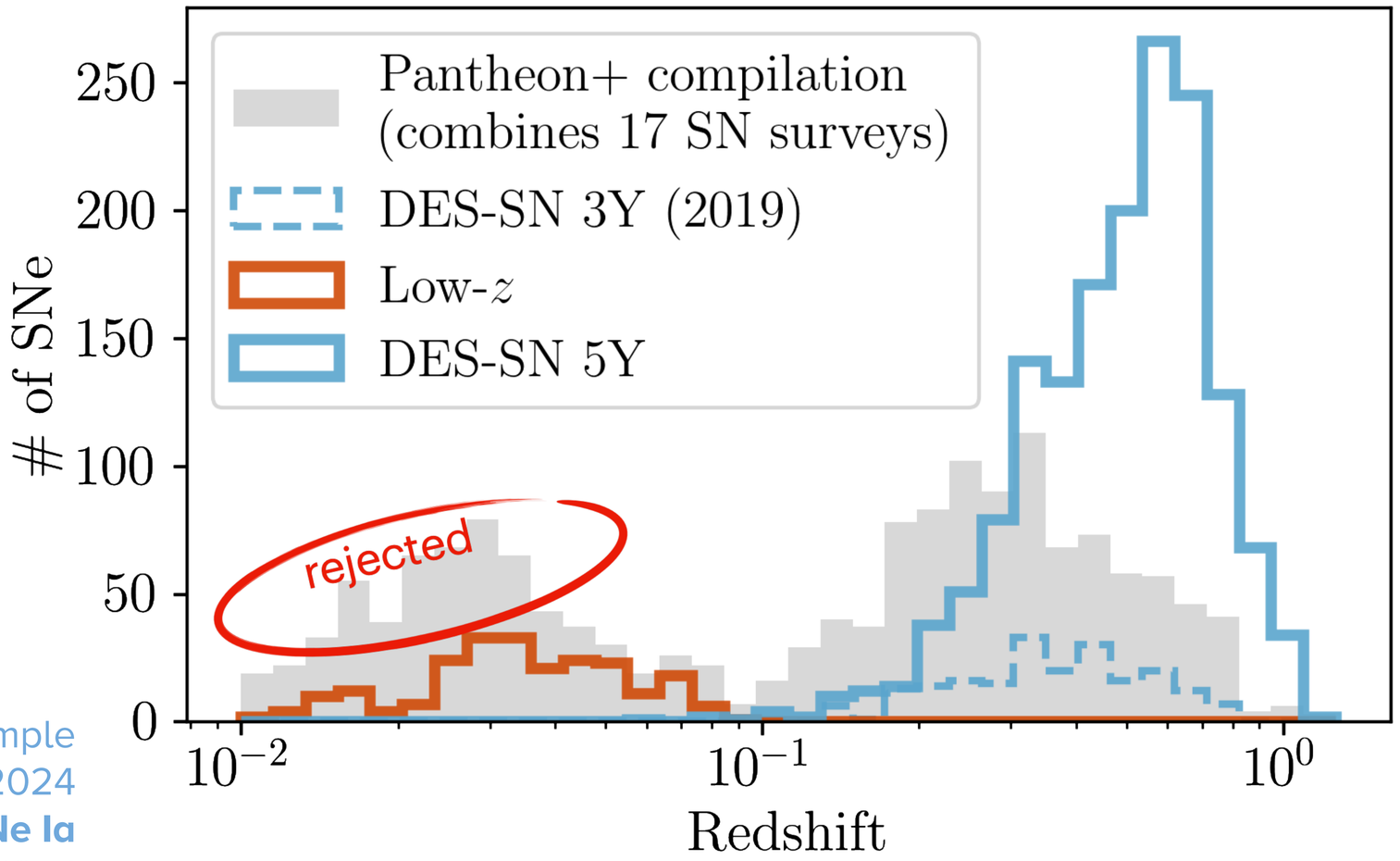
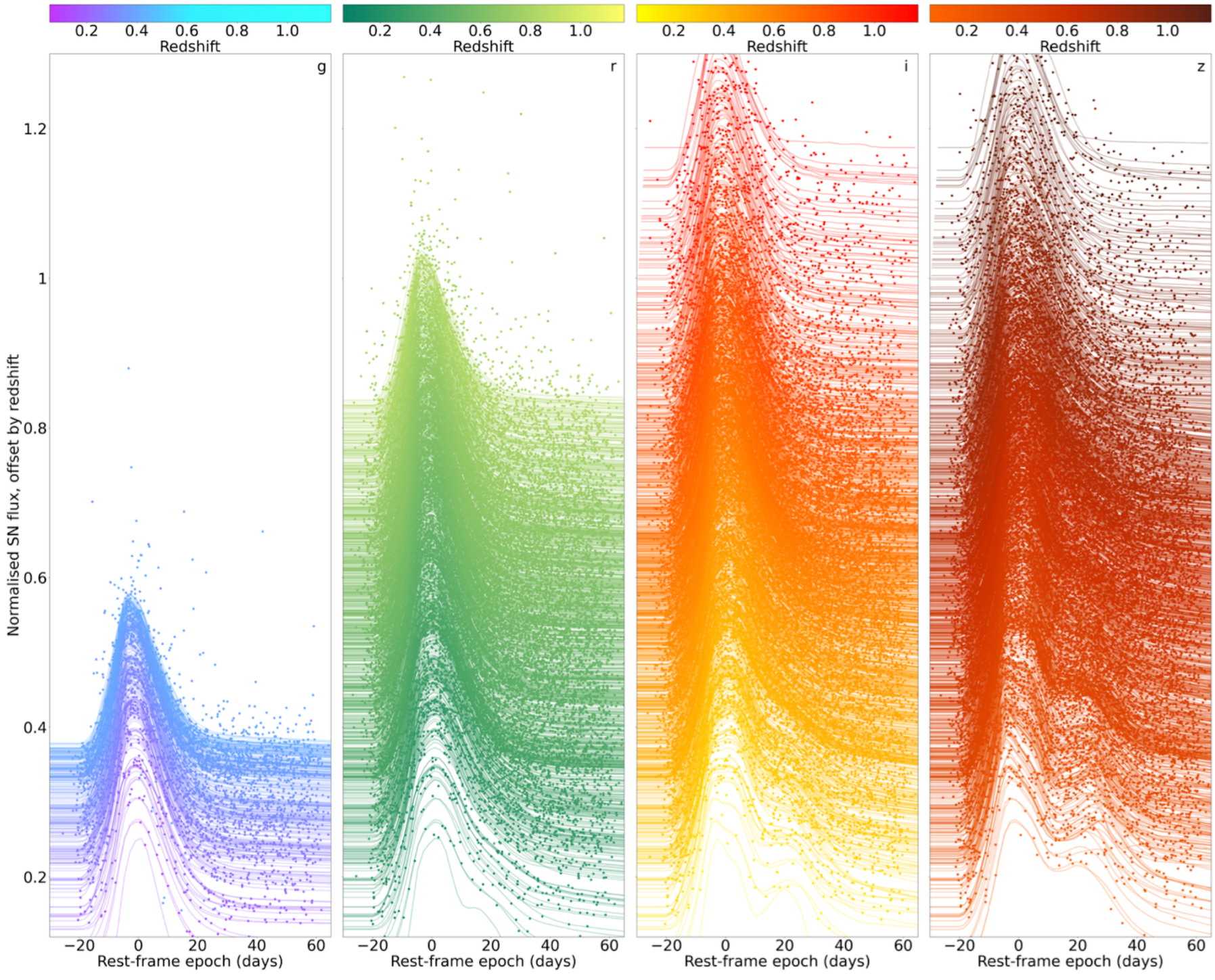


Pantheon+ and **Union** compilations
Brout et al. 2021
Rubin et al. 2024

DES-SN5YR sample
DES 2024
Approx 1500 new SNe Ia
Photometrically classified

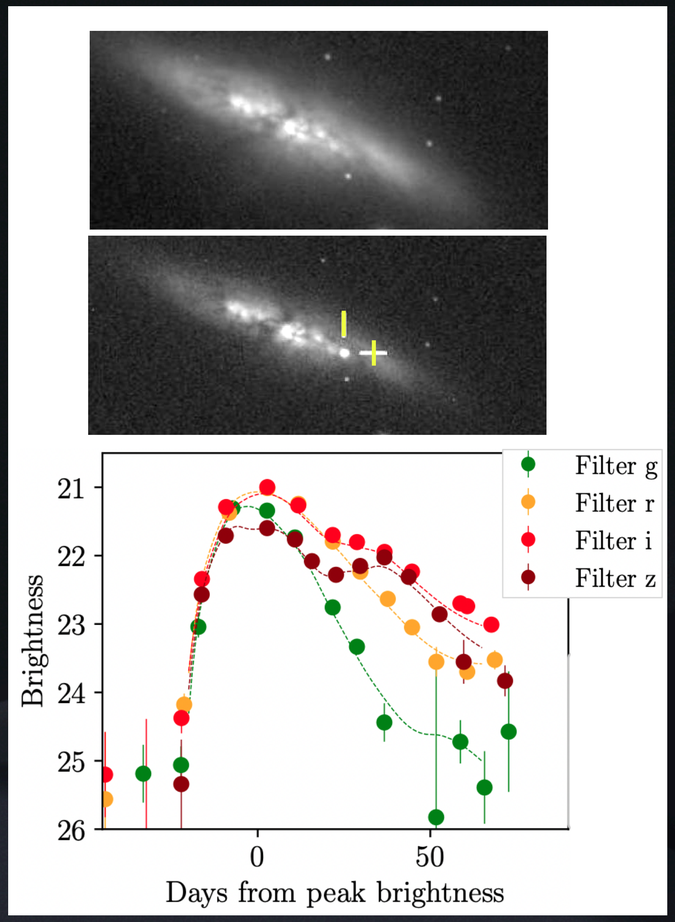
The DES Supernova Light Curves

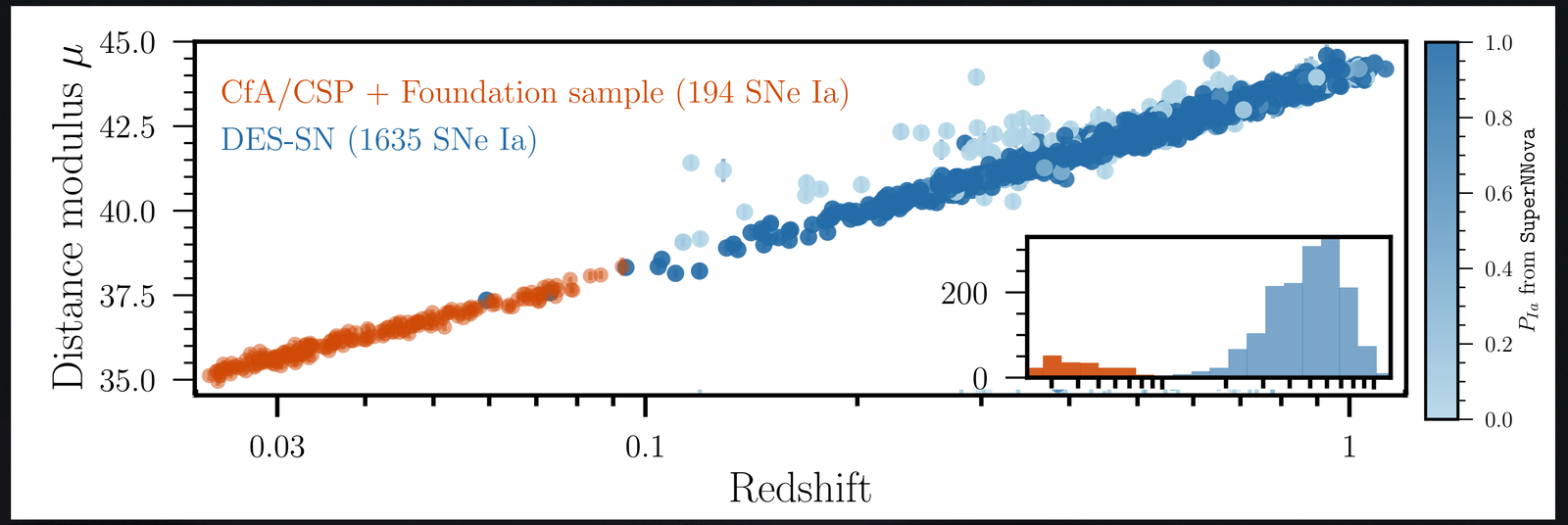
All of our SN Ia light curves (offset by redshift)

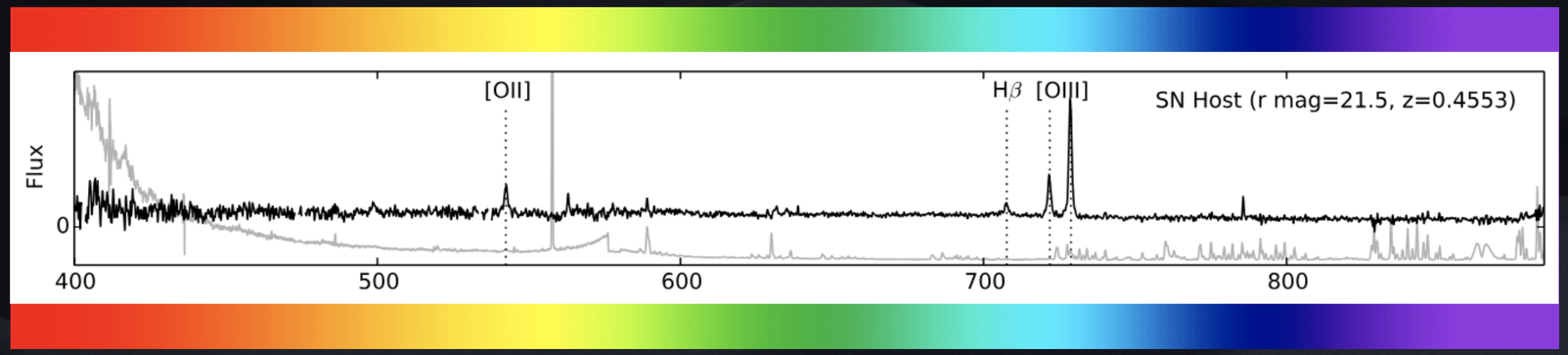


DES Hubble Diagram

Magnitude (DECam)





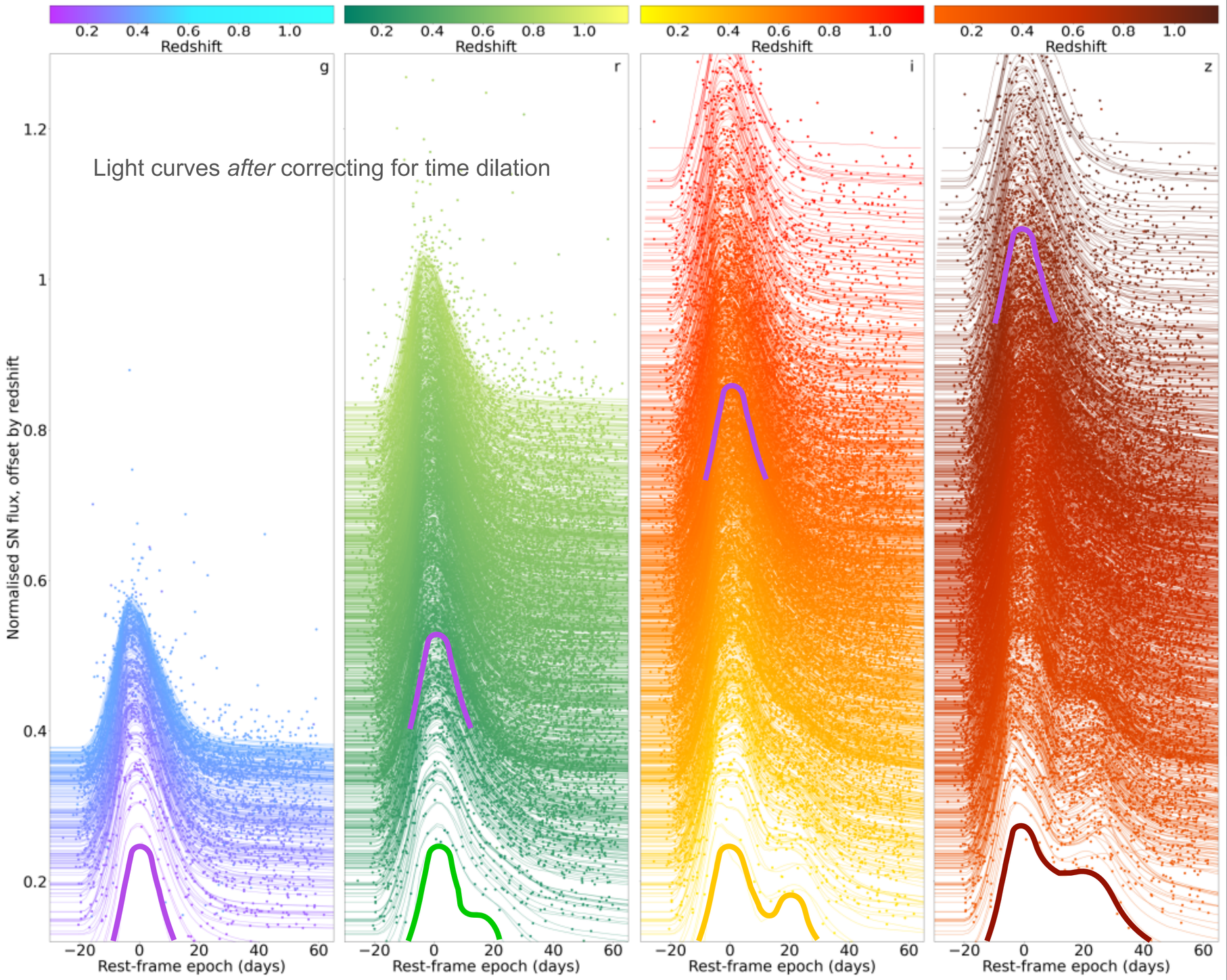


Redshift (AAT)

Time Dilation

Ryan White et al.
arXiv:2406.05050

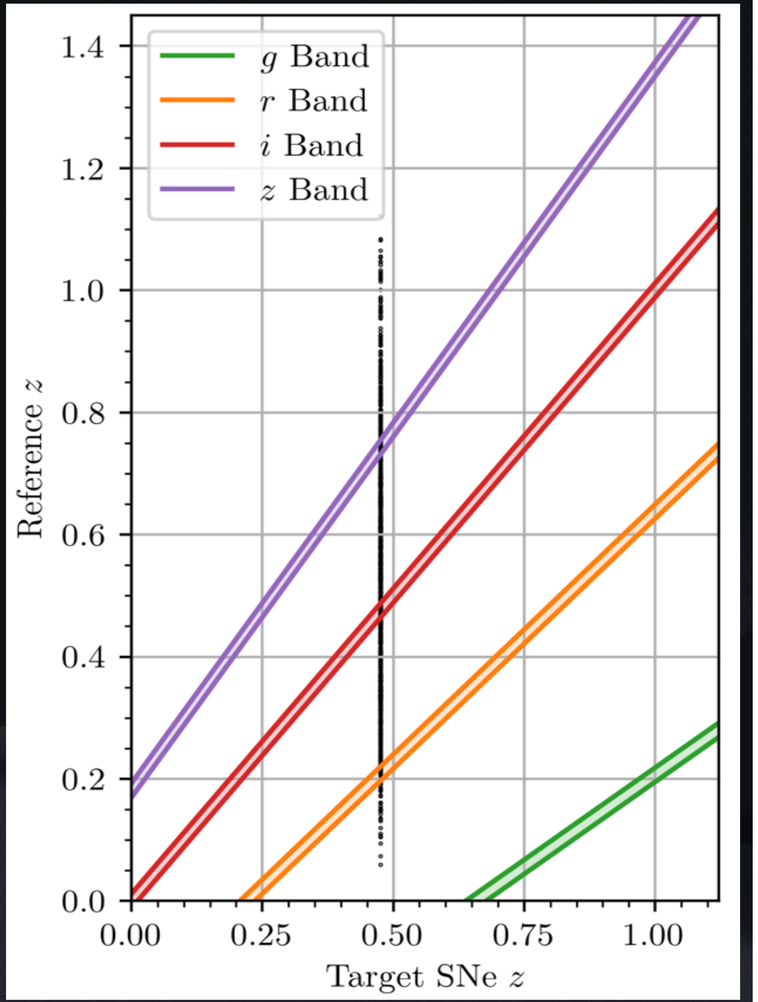
Light curves *after* correcting for time dilation



White et al. arXiv:2406.05050

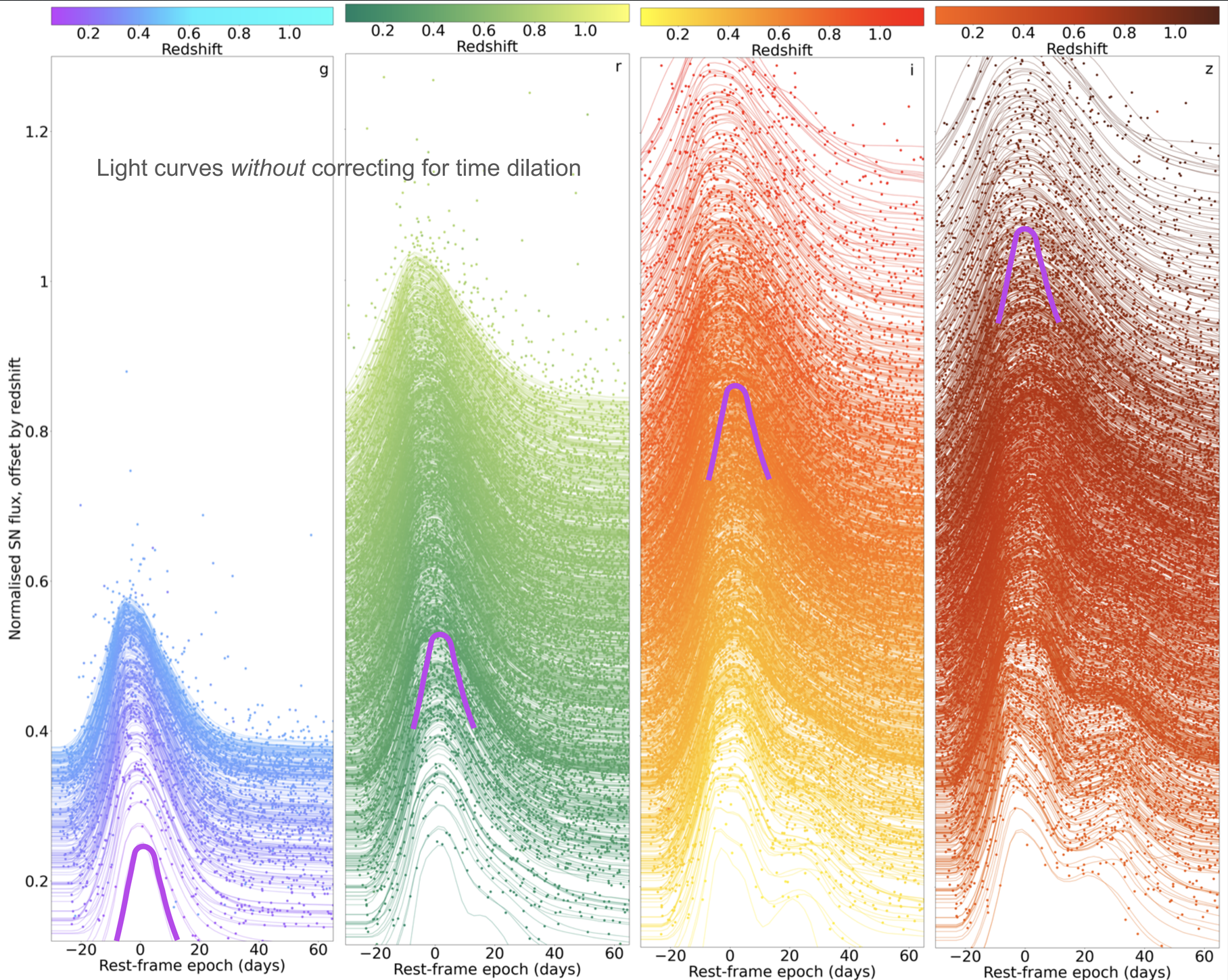
Time Dilation

Pick light curves sampling the same colours



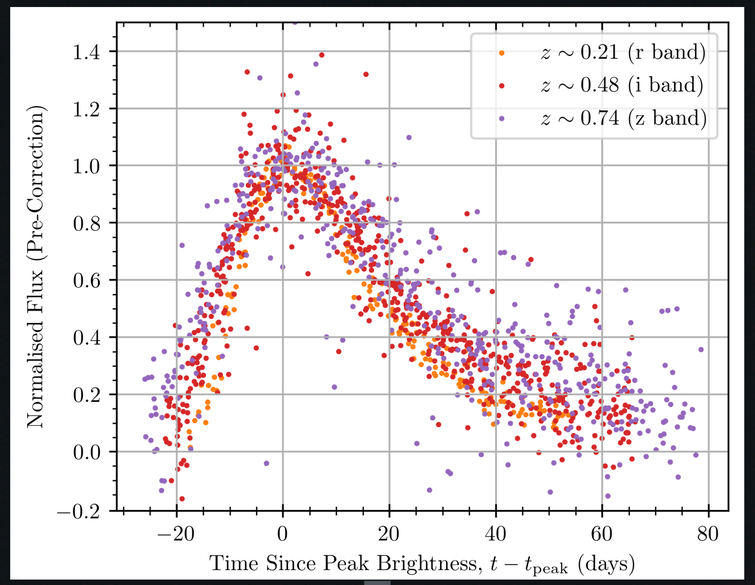
White et al. arXiv:2406.05050

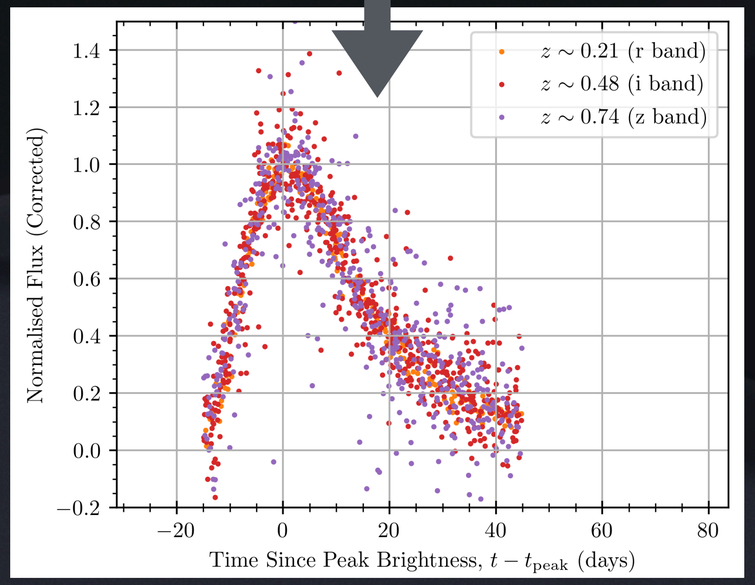
Light curves *without* correcting for time dilation

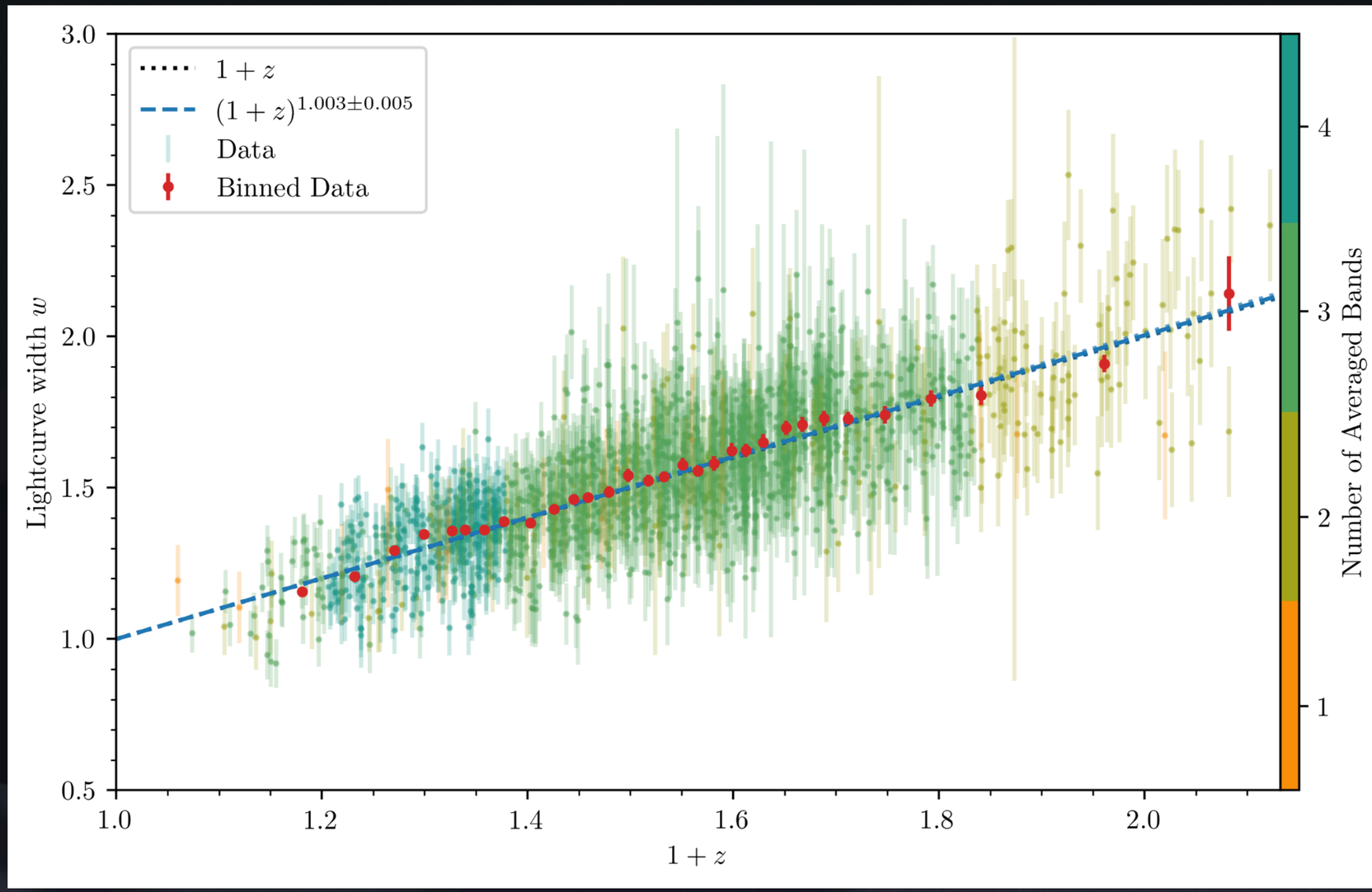


Time Dilation

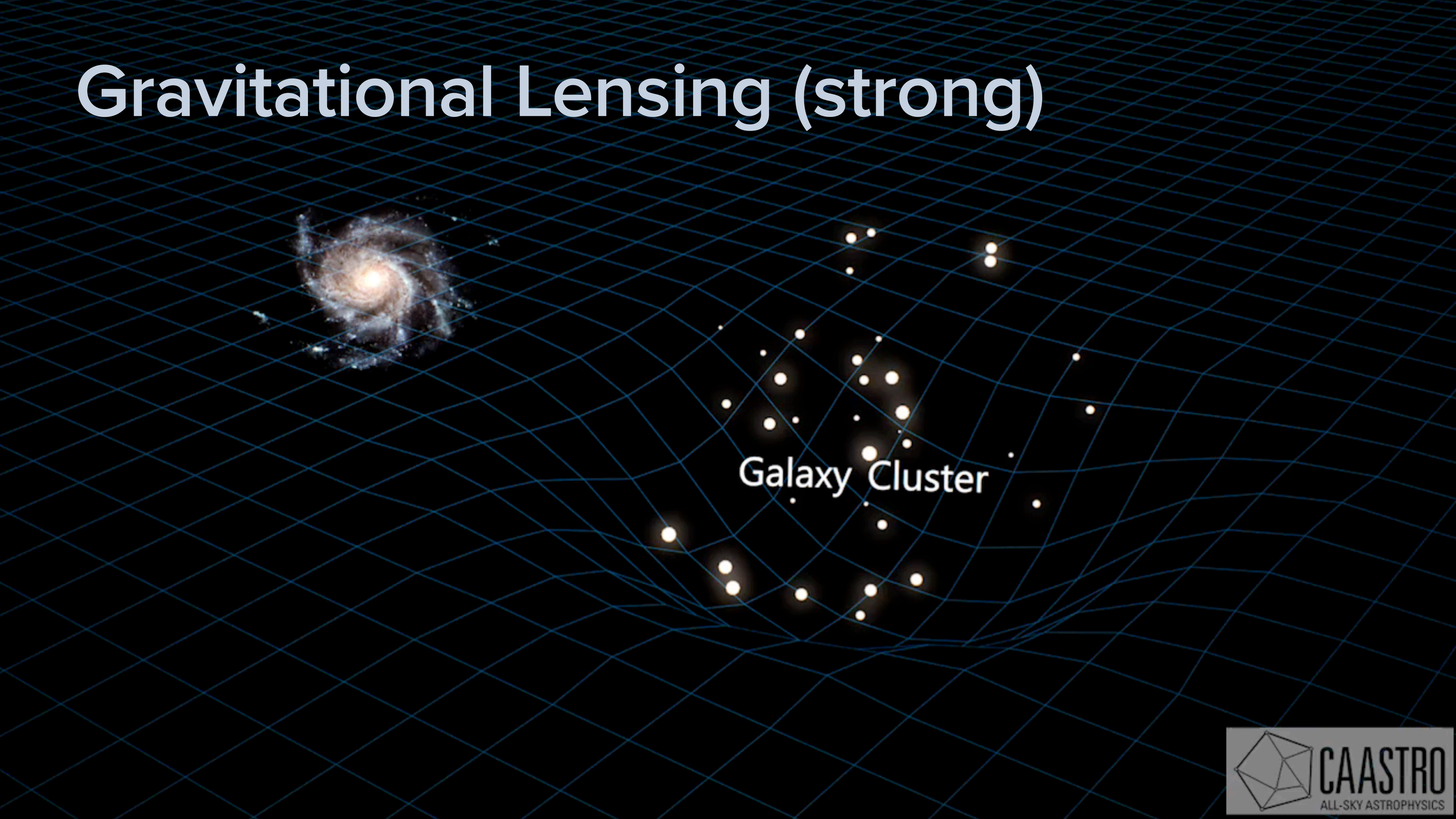
White et al. arXiv:2406.05050







Gravitational Lensing (strong)



Gravitational Lensing (weak)

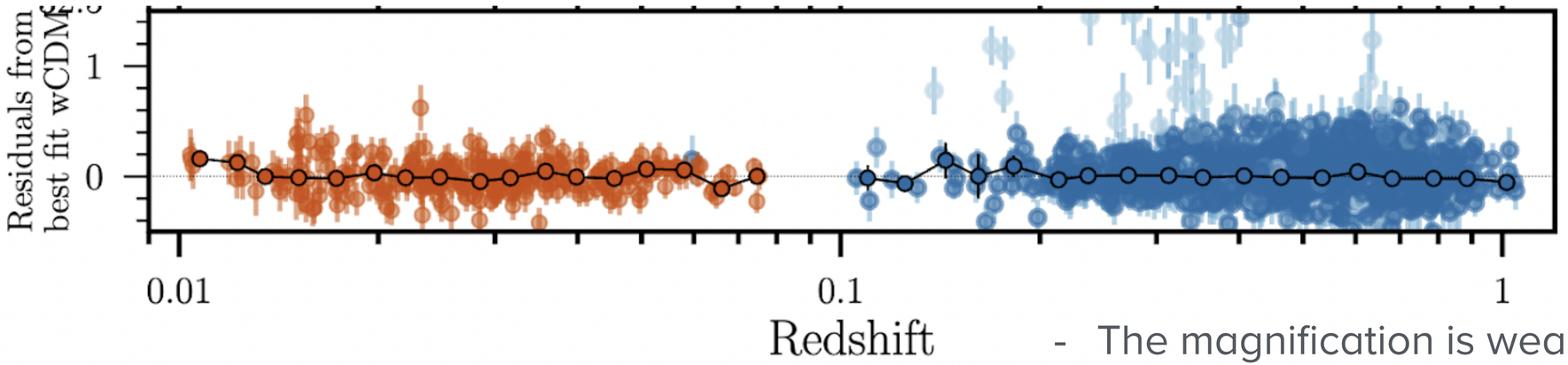
Galaxies

CAASTRO
ALL-SKY ASTROPHYSICS

Shah et al. arXiv:2406.05047

Gravitational Lensing Magnification

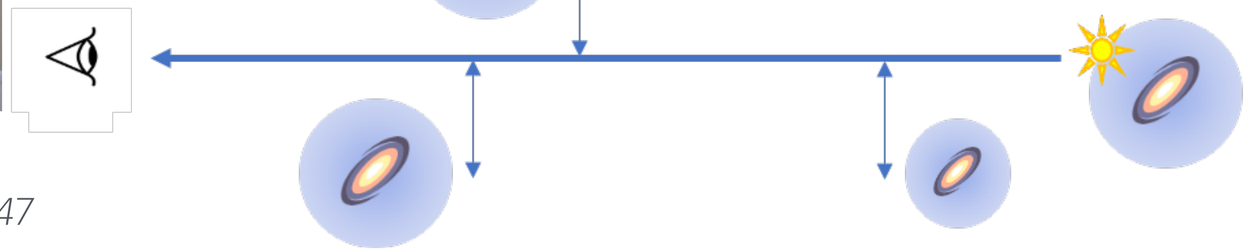
- What can Type Ia supernovae tell us about inhomogeneity?



Some of this "noise" is signal.

- The magnification is weak, typically ~2.5% at redshift z = 0.5
- SN Ia are intrinsically variable by ~15%

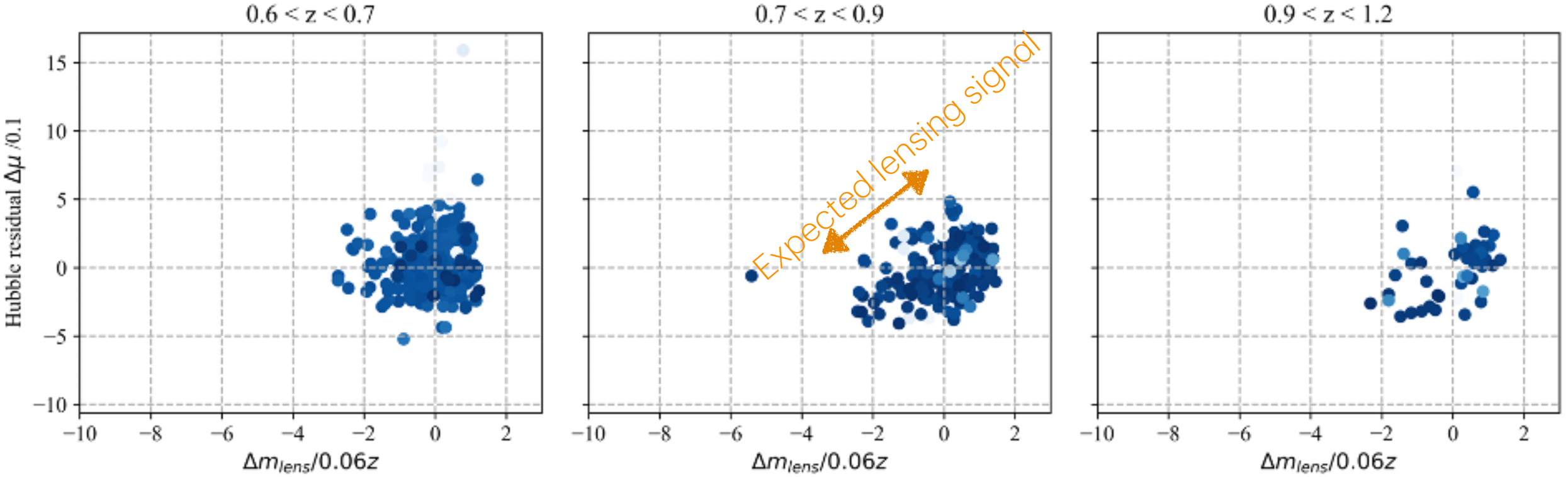
Paul Shah et al.
arXiv:2406.05047



- Technique:
  - Model matter as haloes surrounding foreground galaxies
  - Correlate Hubble diagram residuals with foreground density
  - Get shape and weight of dark matter haloes!

Shah et al. arXiv:2406.05047

Gravitational Lensing Magnification



Detected weak lensing magnification of SNe at >5 σ for the first time

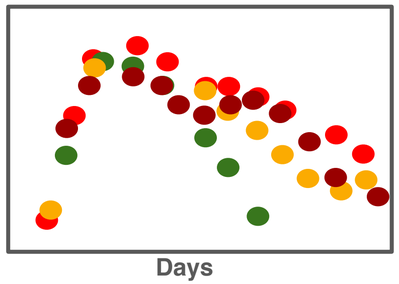
Can correct luminosity distances for lensing

- Moves wCDM slightly closer to ΛCDM :
  - $\Delta\Omega_M = +0.036, \Delta w = -0.056$

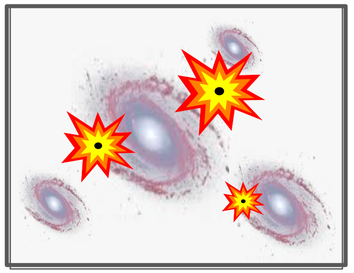
Put constraints on how much black holes can contribute to dark matter.

Constrain shape of dark matter haloes.

DES Analysis Details

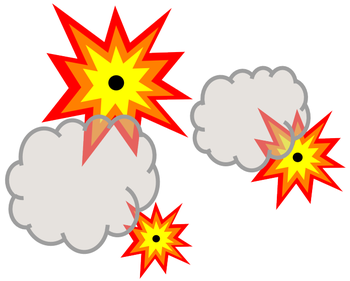


1. Building the Data Set: find SNe, **calibrate** photometry, get host redshifts



2. Simulating DES-SN5YR: samples that looks like the *observed* sample

3. Classify SNe Ia: Machine Learning



4. Modelling: SN dust, progenitors, physics

DES-SN5YR analysis overview

Data:
- Calibration (Burke et al. 2018, Brout et al. 2022, Rykoff et al. 2023)
- SN photometry (Brout et al. 2019, Sanchez et al. 2024)
- SN spectroscopy (Smith et al. 2020a)
- DCR and chrom (Lasker et al. 2018, Lee&Acevedo et al. 2023)
- Host galaxy redshifts and properties (Lidman et al. 2020, Carr et al. 2021, Wiseman et al. 2020/2021, Kelsey et al. 2023)

Simulations:
- Survey selection effects (Kessler et al. 2019a, Vincenzi et al. 2020)
- SN Ia intrinsic and dust properties (Brout&Scolnic 2021, Popovic et al. 2021a/b, Wiseman et al. 2022) and rates (Wiseman et al. 2021)
- Contamination (Vincenzi et al. 2019/2020, Kessler et al. 2019b)

Analysis:

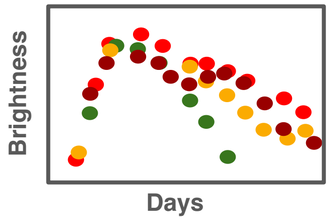
Pipeline and Overview (Hinton et al. 2020, Vincenzi et al. 2024)
- Light-curve fitting (Taylor et al. 2023)
- SN classification (Möller & de Boissière 2020, Qu et al. 2021, Vincenzi et al. 2021, Moller et al. 2022)
- "BEAMS" and bias corrections (Kessler & Scolnic 2017), unbinning the SN Hubble diagram (Brout et al. 2020, Kessler et al. 2023)
- Effects of host galaxy mismatch (Qu et al. 2023)
- Cosmological contour validation (Armstrong et al. 2023)

Cosmological results: DES Collaboration 2024

Testing non-standard cosmological models (Camilleri et al. 2024)

DES Analysis Details

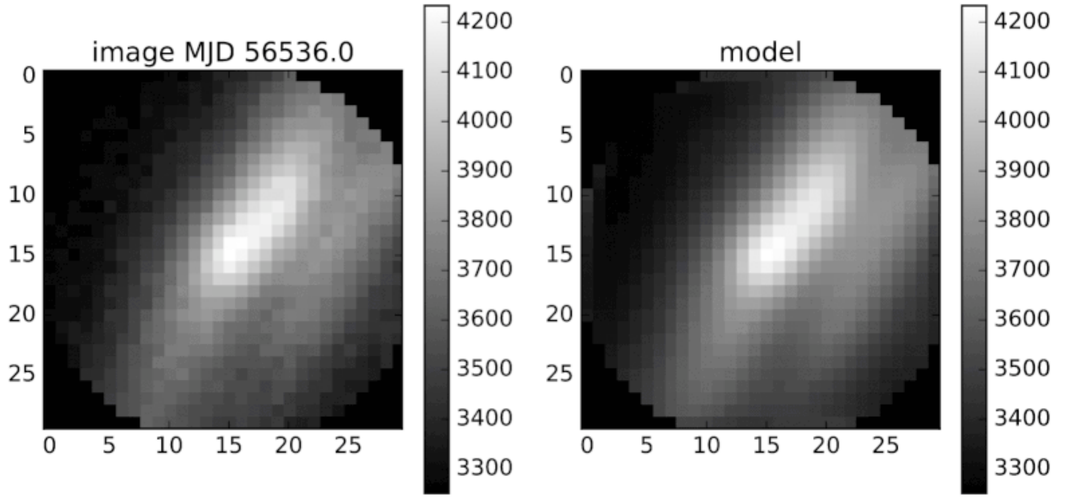
Calibration:

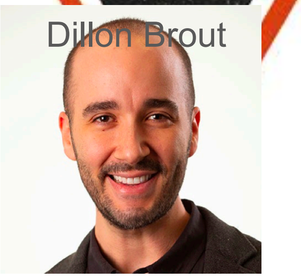


Photometry calibrated to 5mmag accuracy

Scene modelling photometry

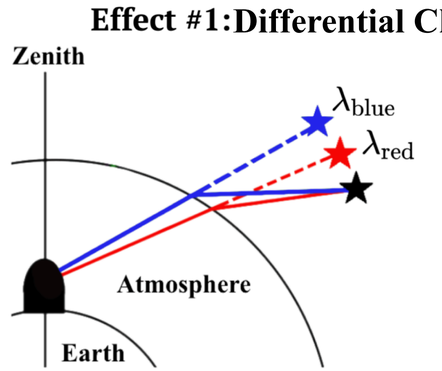
Brout et al. 2019,
Sanchez et al. 2024

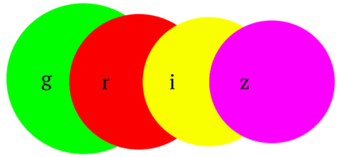


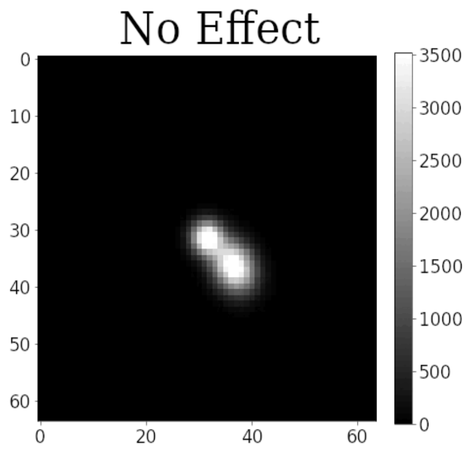


Account for atmospheric effects

Lee, Acevedo,
Sako et al. 2022

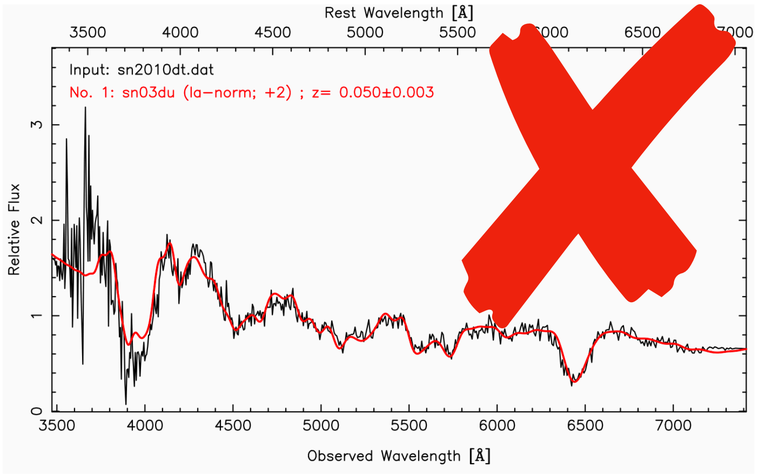


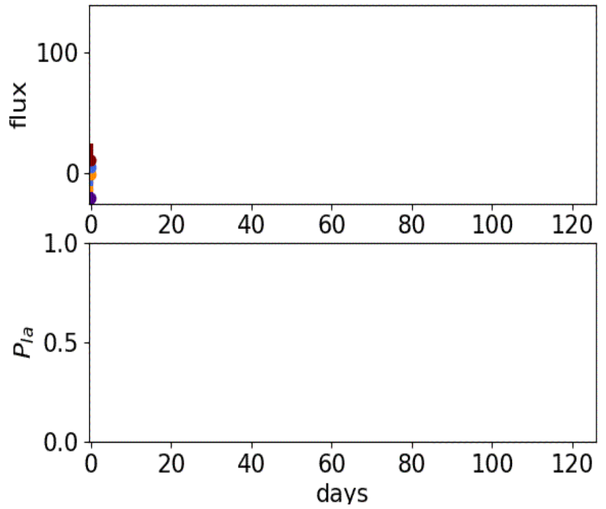




DES Analysis Details

Photometric classification of ~20,000 candidates:





Three SN classification algorithms
Seven non-Ia simulation variants (for independent train/test)

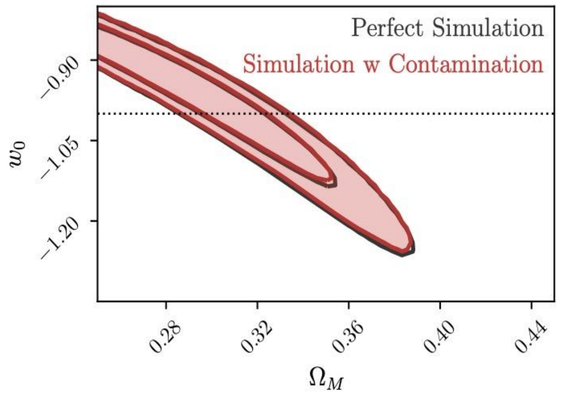
Classifiers **perform remarkably well:**
>98.5% purity
>99.0% efficiency

SuperNNova (Anais Moller et al. 2019)

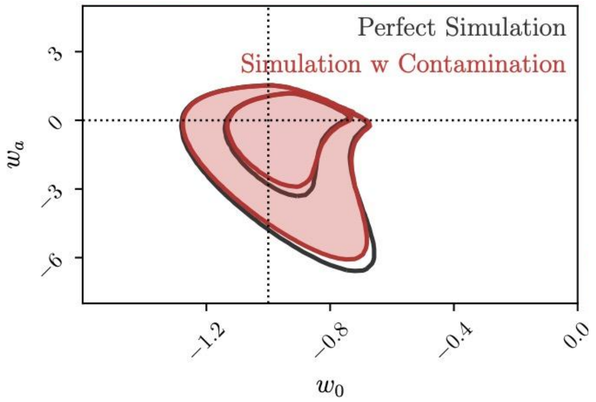
SCONE (Helen Qu et al 2019)

SNIRF (Kovacs & Kuhlmann)

wCDM - Simulations



w0waCDM - Simulations



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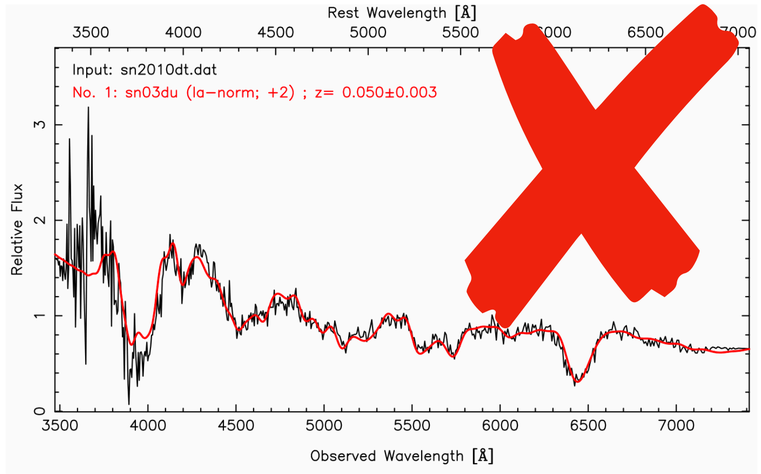

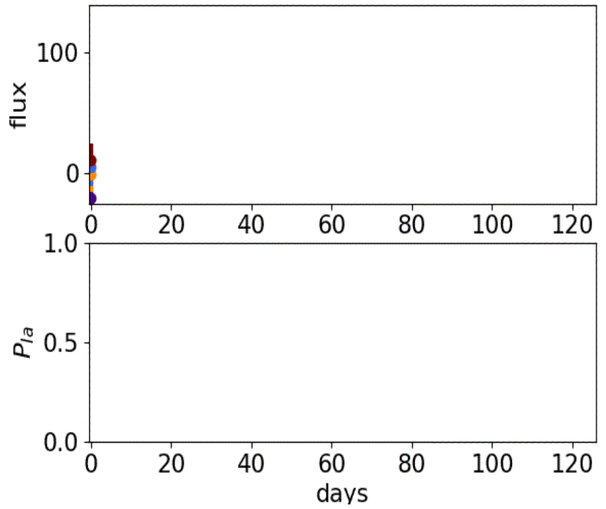

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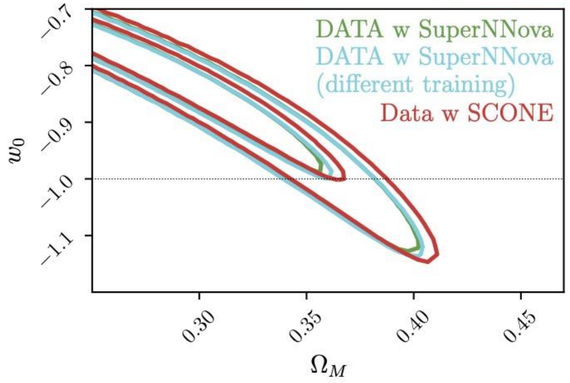
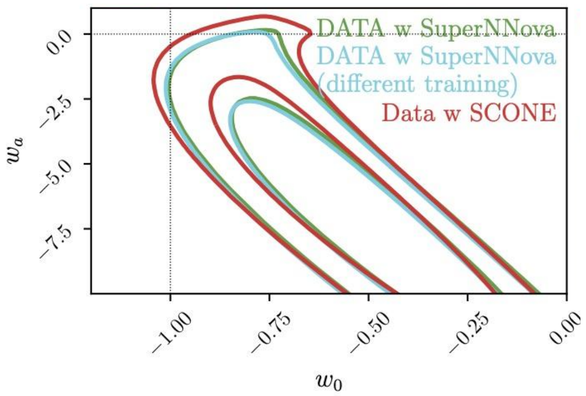
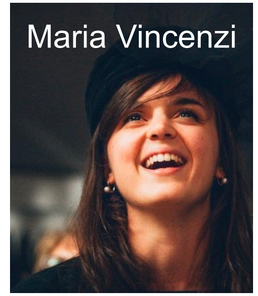


w0waCDM - Simulations

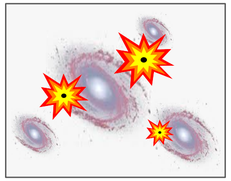


Effects of **contamination** << statistical **uncertainties**

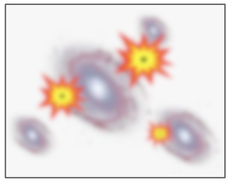
DES Analysis Details



Simulating the sample:

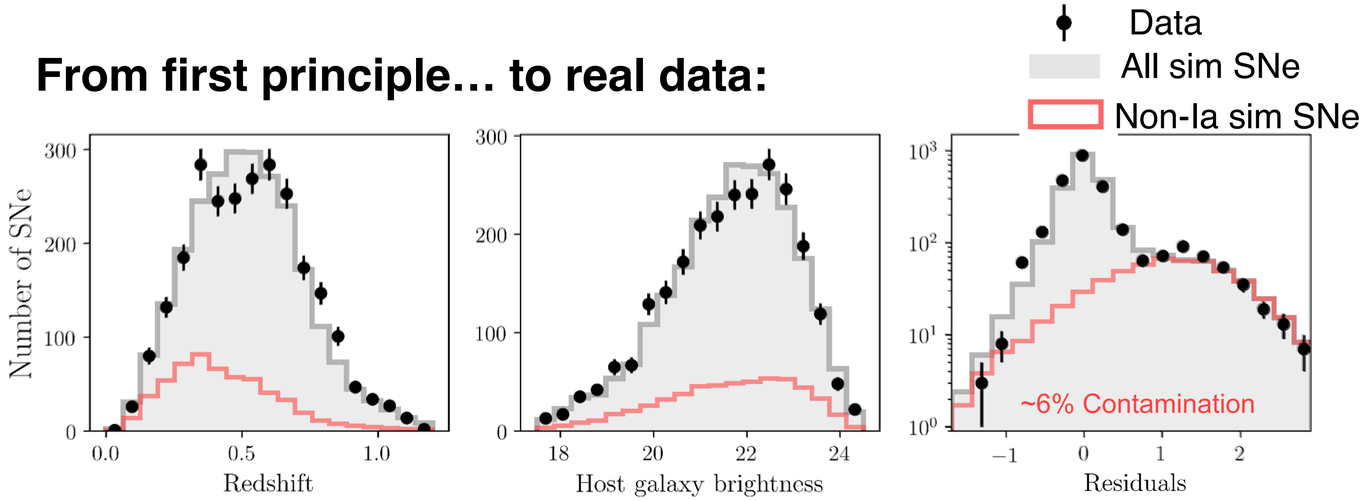


Astrophysical components:
- SN Type Ia + “contaminants”
- **Host galaxies** and dust



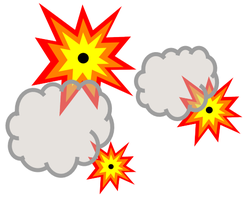
Survey properties:
- observational noise,
- cadence,
- spectro-z selection

From first principle… to real data:



Kessler et al 2019,
Vincenzi et al. (2021, 2023),
Qu et al. 2023

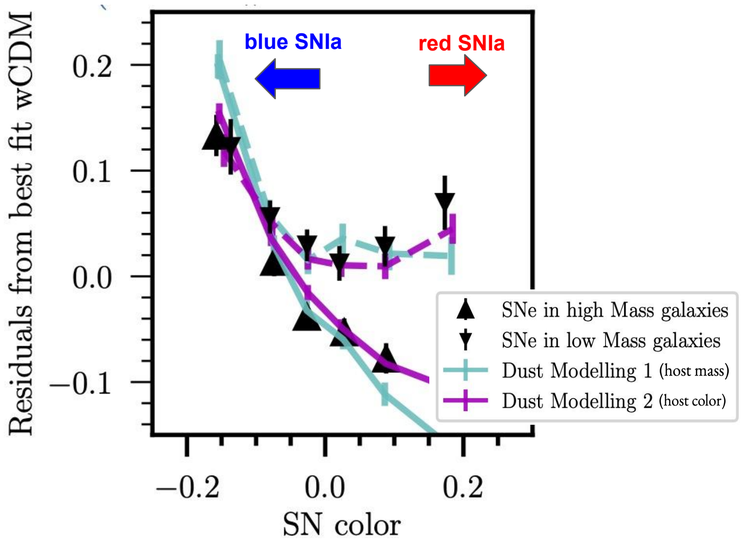
DES Analysis Details



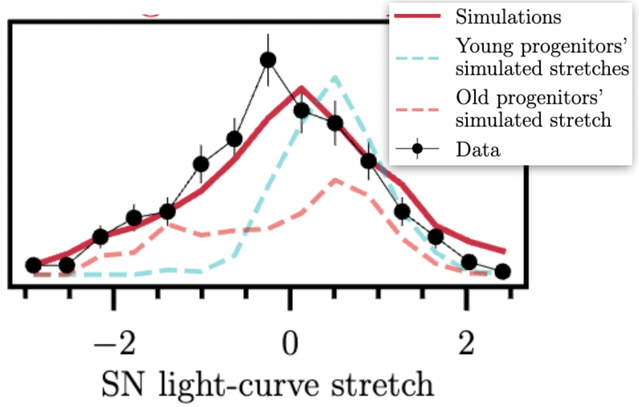
Modelling dust extinction and SN progenitors

Brodie Popovic, Phil Wiseman, Rebecca Chen, Lisa Kelsey

Extrinsic origin:
Modelling dust properties…



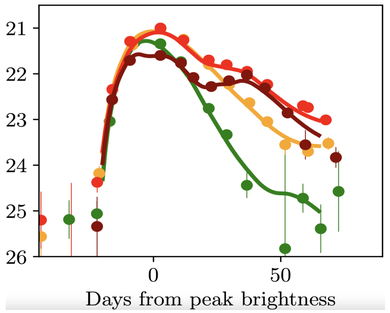
Intrinsic origin:
Modelling correlations between SN age / SN host / SN stretch



Rigault et al. 2019,
Nicholas et al. 2021,
Wiseman, Vincenzi et al. 2021,
Brout and Scolnic 2021,
Popovic et al., 2021,
Chen et al., 2022

DES Analysis Details

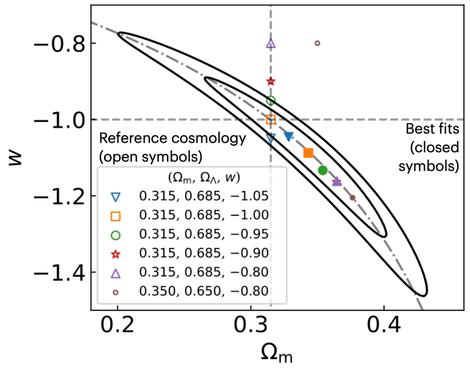
Set new standards in multiple areas



The first SN Ia cosmological analysis to use a new light-curve model: SALT3

- SALT3 trained on x1.5 larger data
- SALT3 goes redder (where DES has high-quality data)
- Calibration uncertainties incorporated in the light-curve model training as well as the fitting.

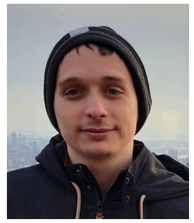
Georgie Taylor et al. 2022



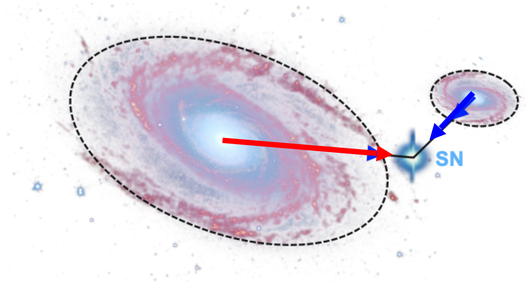
Validated contours, assumptions, and uncertainties

- Only weak dependence on simulation cosmology
- Contour sizes are accurate (including at the extremes)

Patrick Armstrong et al. 2022

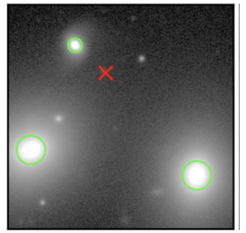


Ryan Camilleri et al. 2024



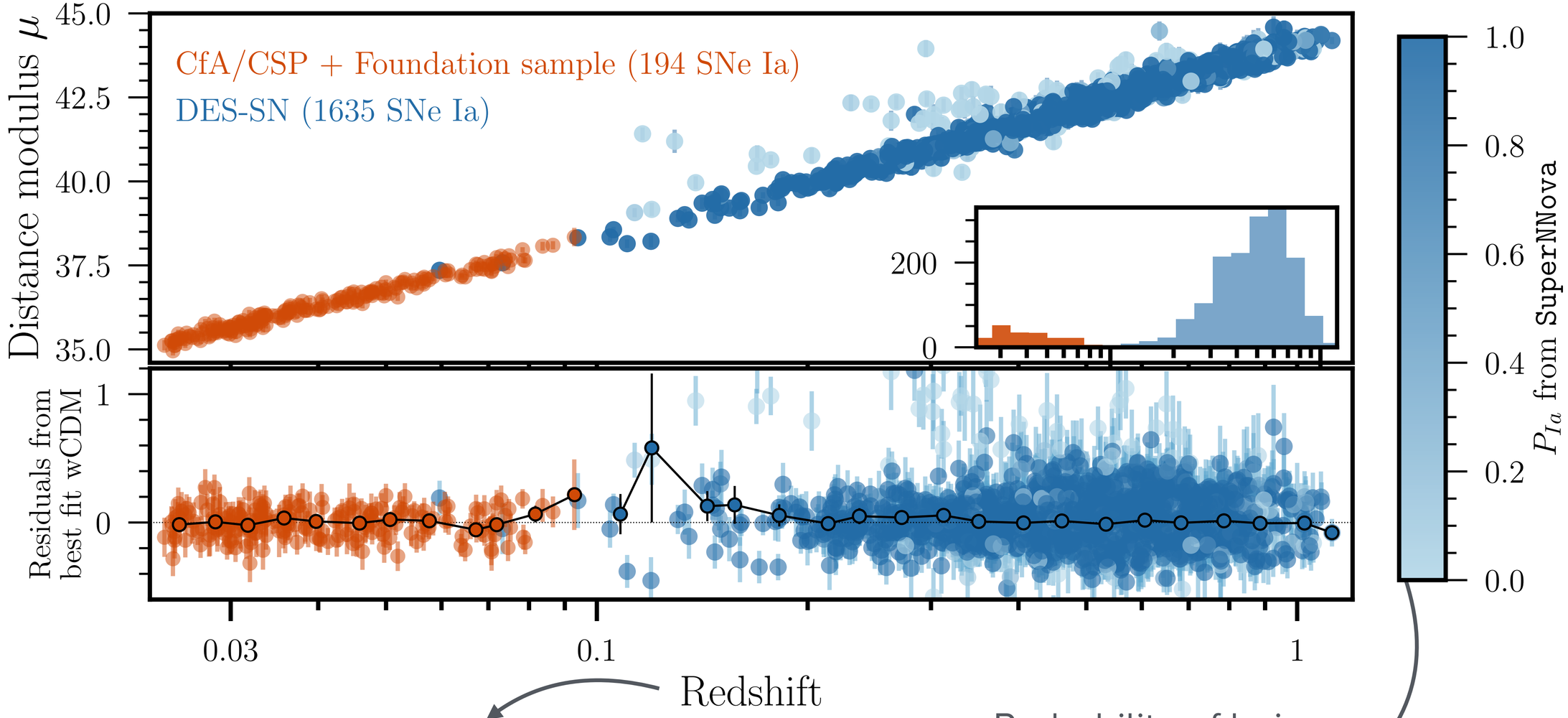
Deep dive on host galaxy associations

- Host Mismatch systematics are less than 10% of total error budget.



Helen Qu et al. 2023

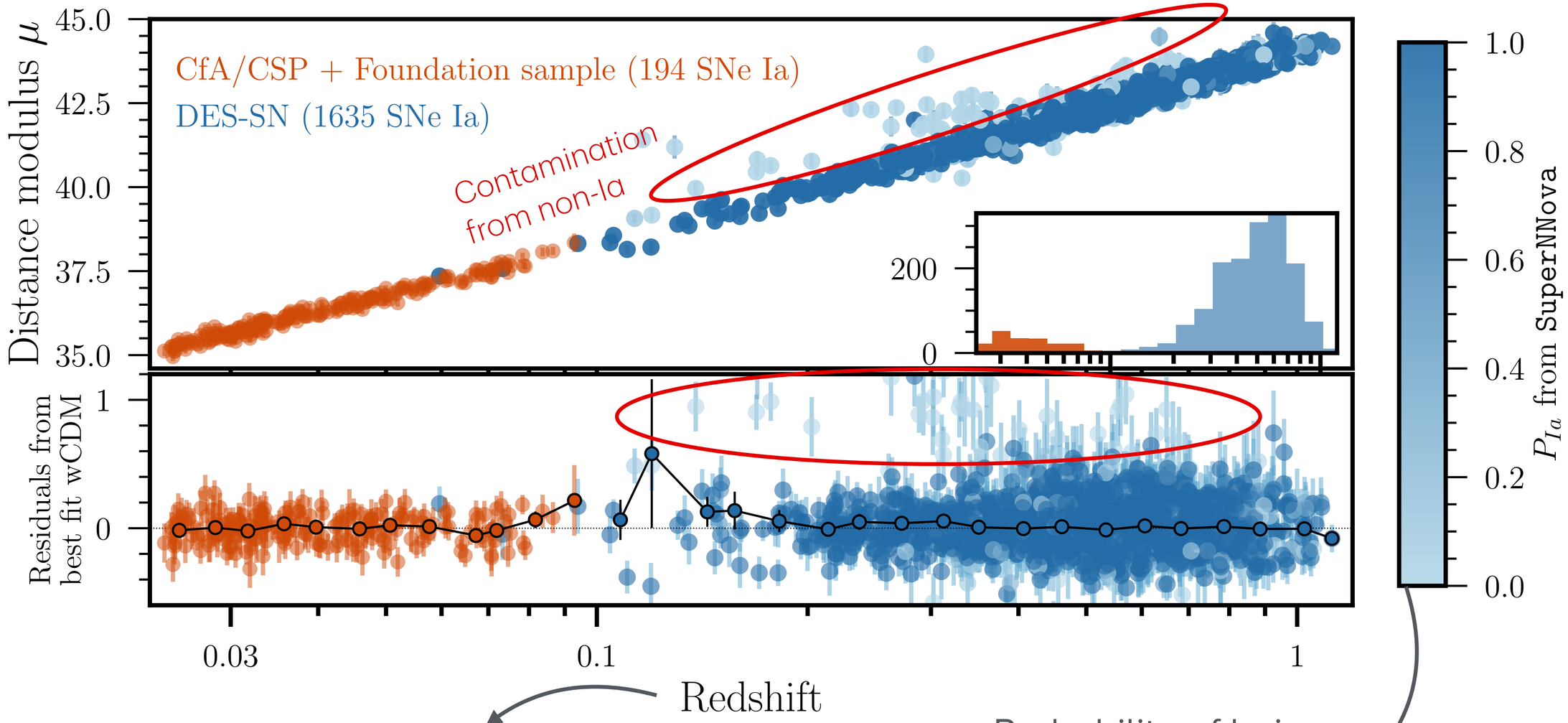
The DES Hubble Diagram



Spectroscopic redshifts from identified host

Probability of being a Type Ia from machine learning

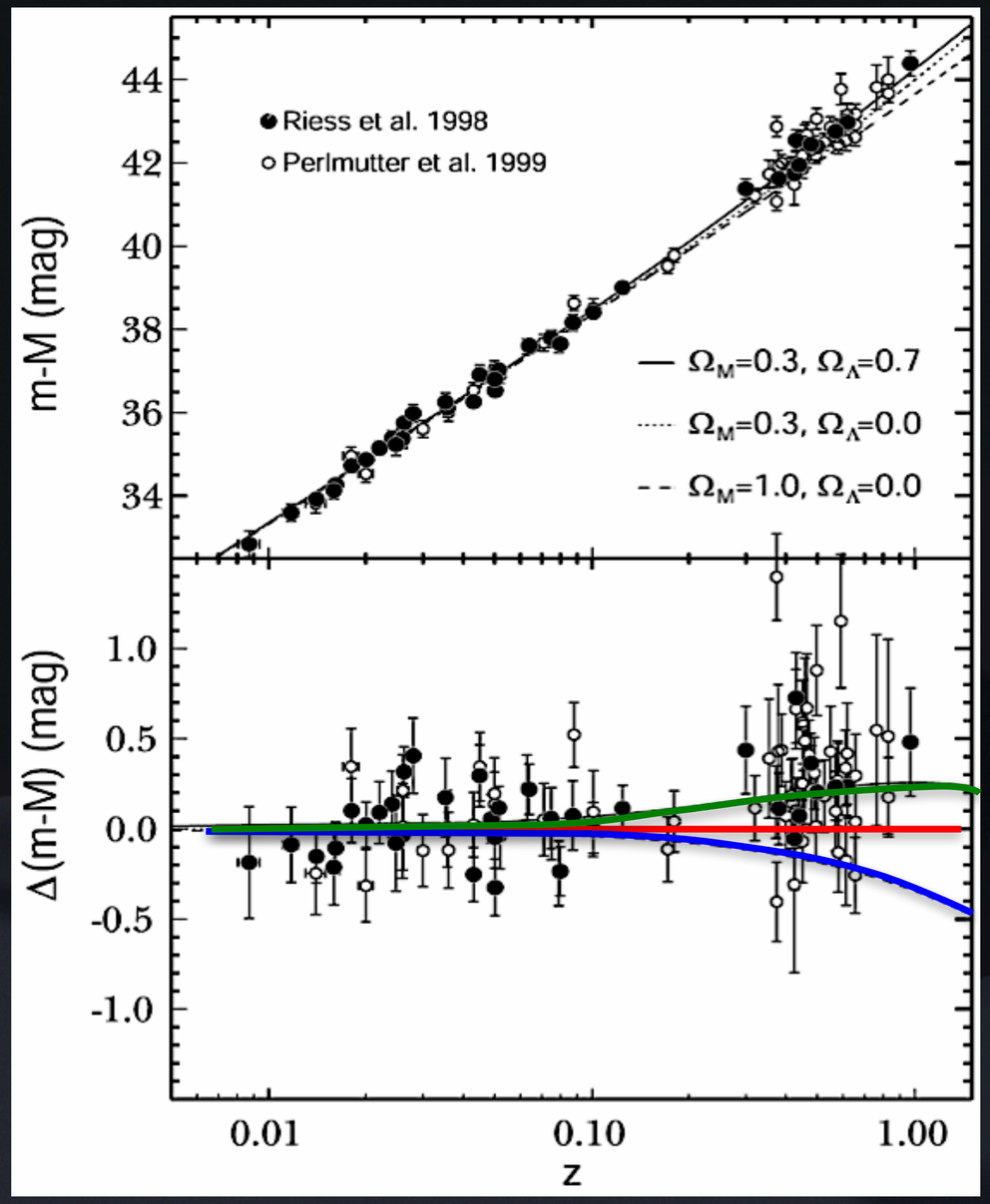
The DES Hubble Diagram



Spectroscopic redshifts from identified host

Probability of being a Type Ia from machine learning

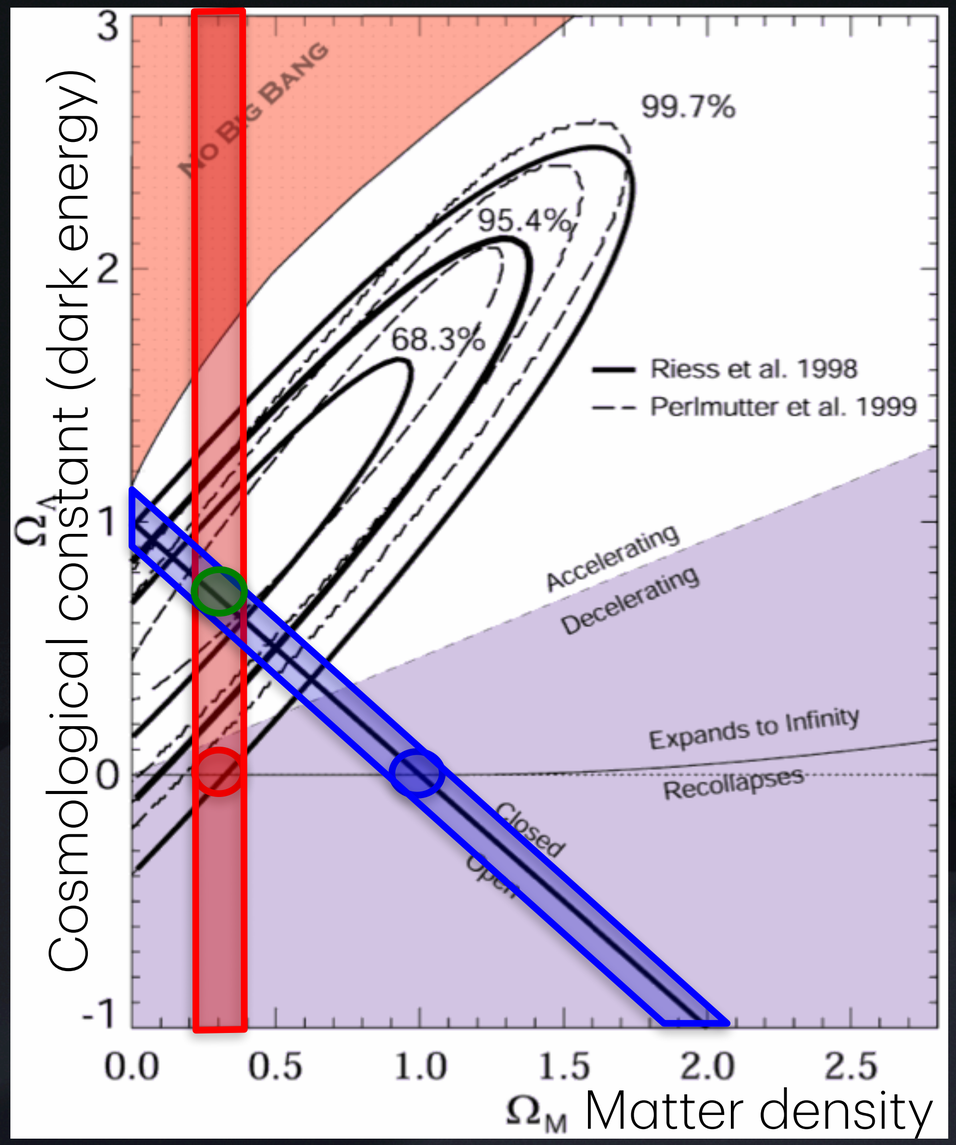
Discovery of Acceleration (dark energy)



Everyone's happy

Observers

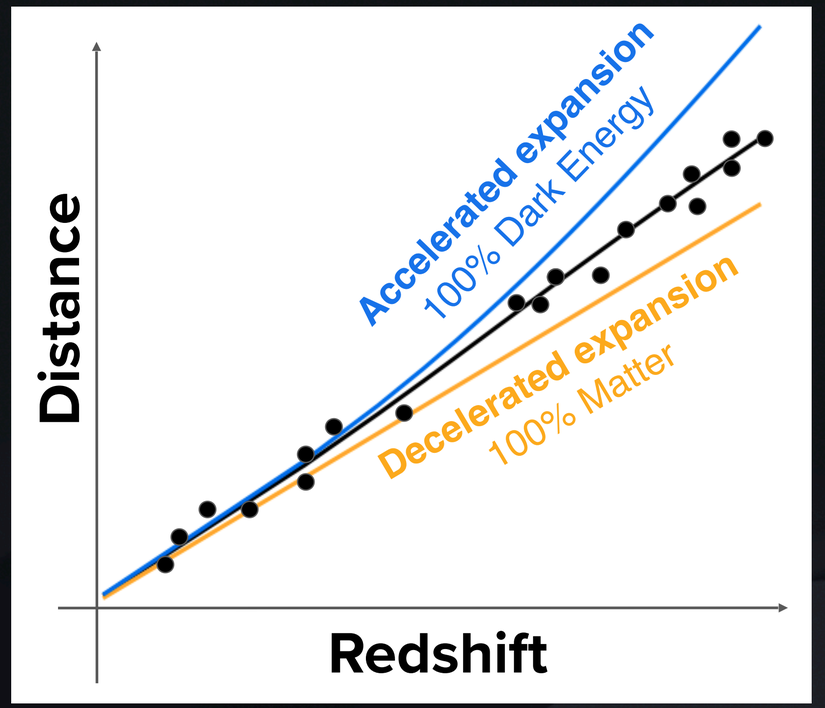
Theorists /CMB

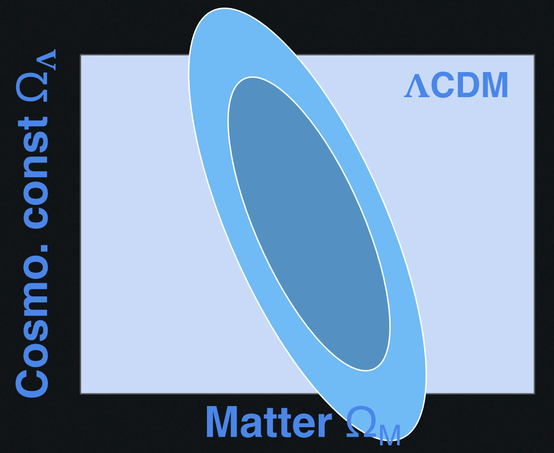


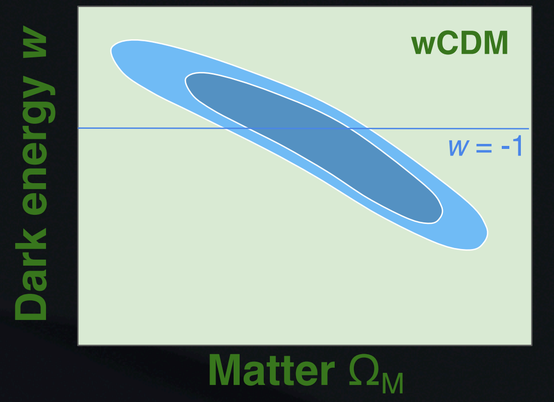
Perlmutter & Schmidt 2003

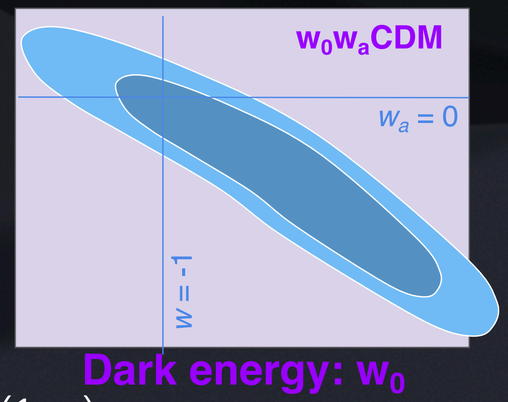
Hubble diagram basics

$$D_L = (1+z)\frac{c}{H_0}\int_0^z \frac{dz}{E(z)}$$





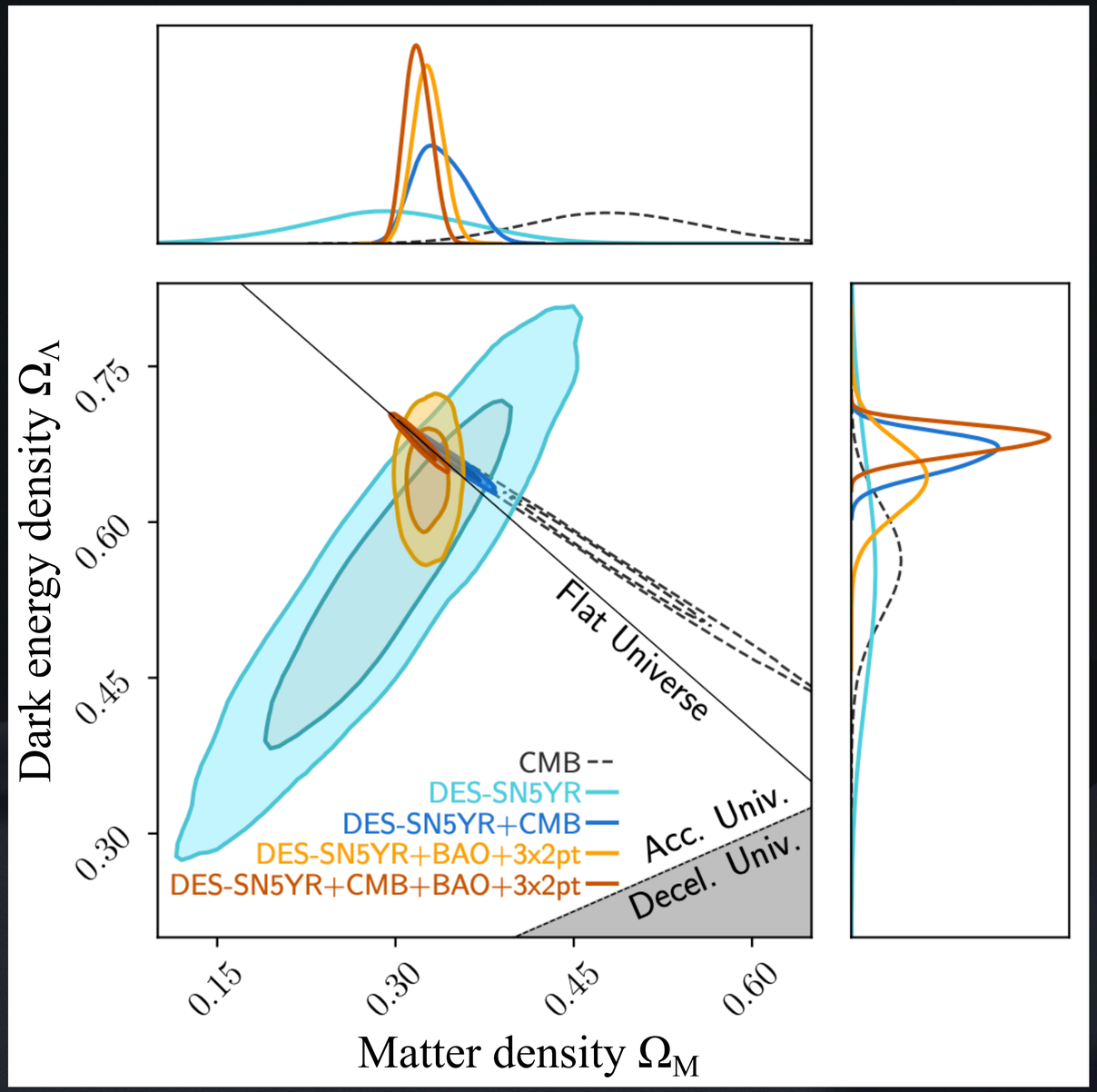




Cosmological Model	Friedmann Equation: $\mathbf{E(z) = H(z)/H_0} =$	Fit Parameters Θ
Flat-ΛCDM	$\left[\Omega_{\rm M}(1+z)^3 + (1-\Omega_{\rm M})\right]^{1/2}$	$\Omega_{\rm M}$
ΛCDM	$\left[\Omega_{\rm M}(1+z)^3 + \Omega_\Lambda + (1-\Omega_{\rm M}-\Omega_\Lambda)(1+z)^2\right]^{1/2}$	$\Omega_{\rm M}, \Omega_\Lambda$
Flat-wCDM	$\left[\Omega_{\rm M}(1+z)^3 + (1-\Omega_{\rm M})(1+z)^{3(1+w)}\right]^{1/2}$	$\Omega_{\rm M}, w$
Flat-w_0w_aCDM	$\left[\Omega_{\rm M}(1+z)^3 + (1-\Omega_{\rm M})(1+z)^{3(1+w_0+w_a)}e^{-3w_a z/(1+z)}\right]^{1/2}$	$\Omega_{\rm M}, w_0, w_a$

$w=w_0+w_a(1-a)$

DES SN Cosmology Results: ΛCDM



DES-SN alone

$\Omega_M = 0.291^{+0.063}_{-0.065}$

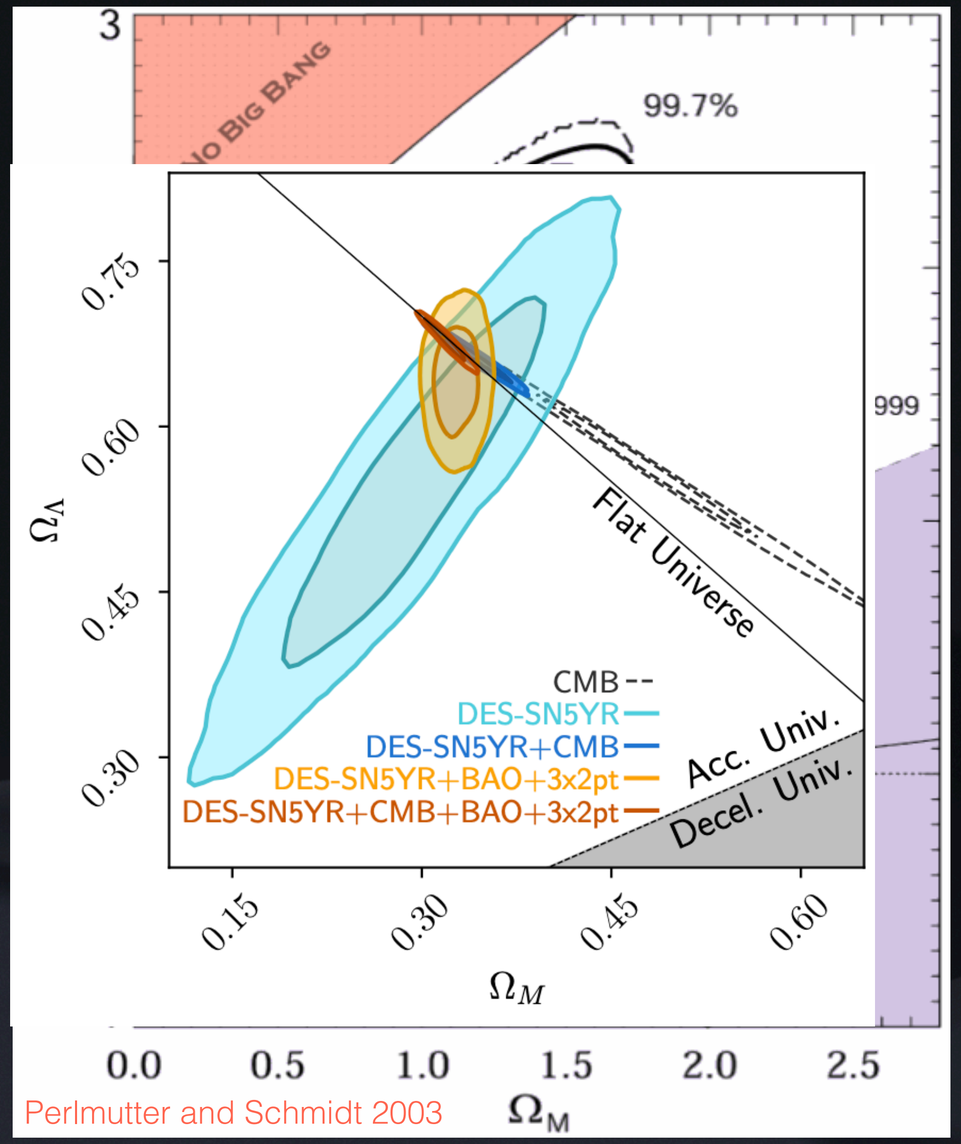
$\Omega_k = 0.16 \pm 0.16$

DES5YR + CMB + BAO + 3x2pt

$\Omega_M = 0.327^{+0.026}_{-0.032}$

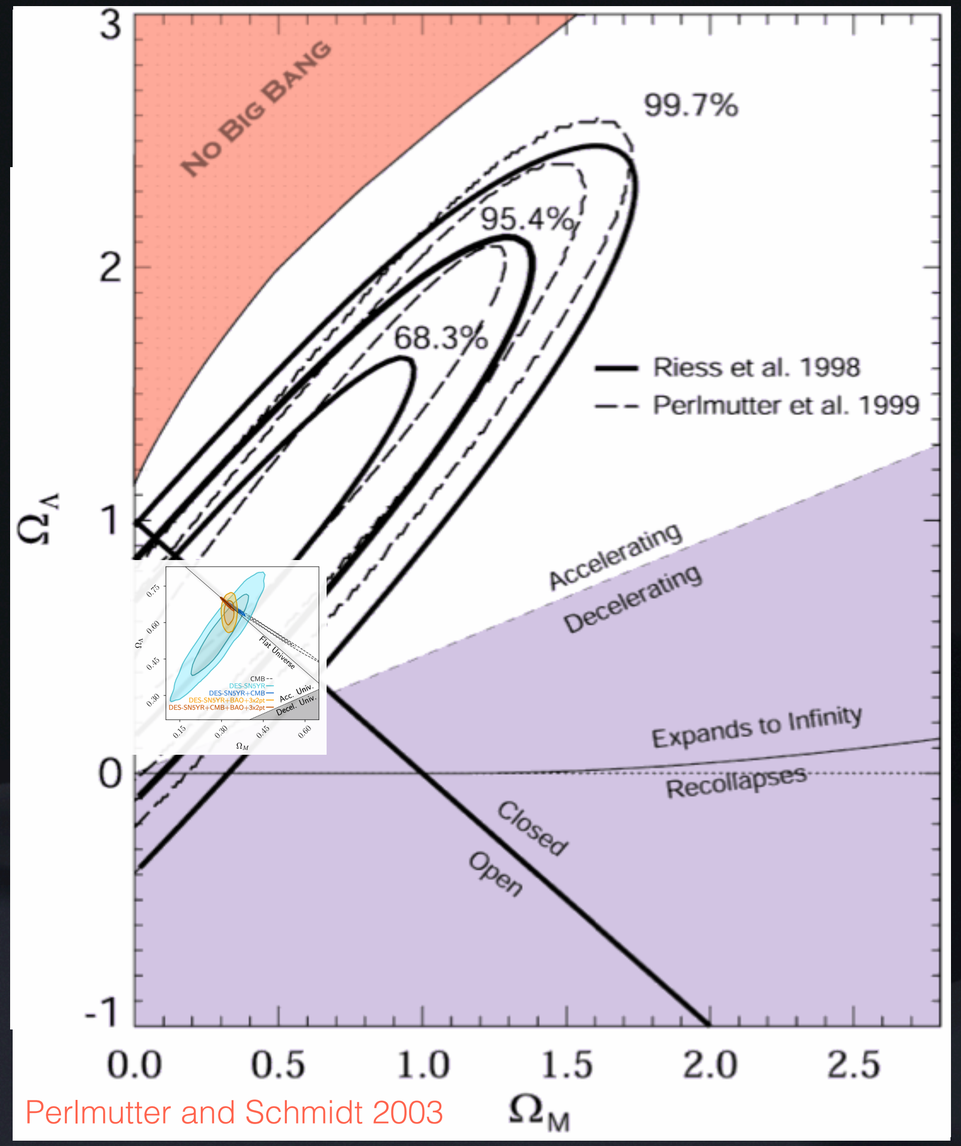
$\Omega_k = 0.010 \pm 0.005$

How far have we come?



Perlmutter and Schmidt 2003

How far have we come?

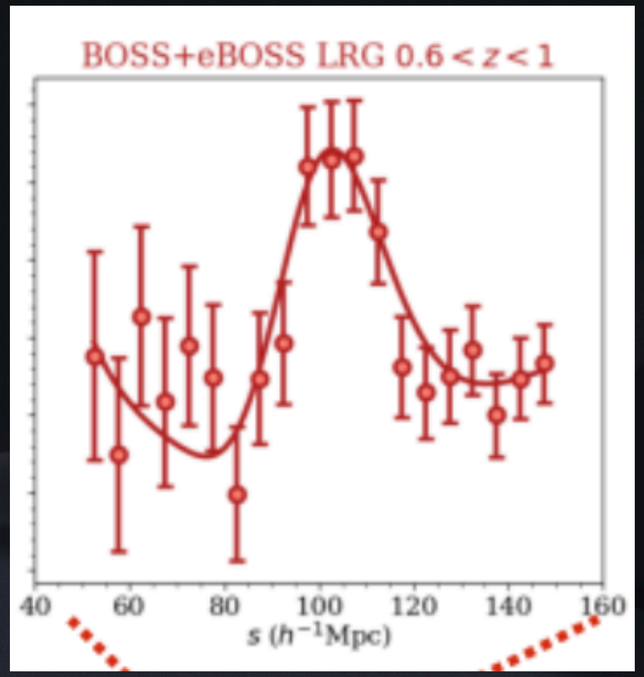


Perlmutter and Schmidt 2003

DES SN Cosmology Results

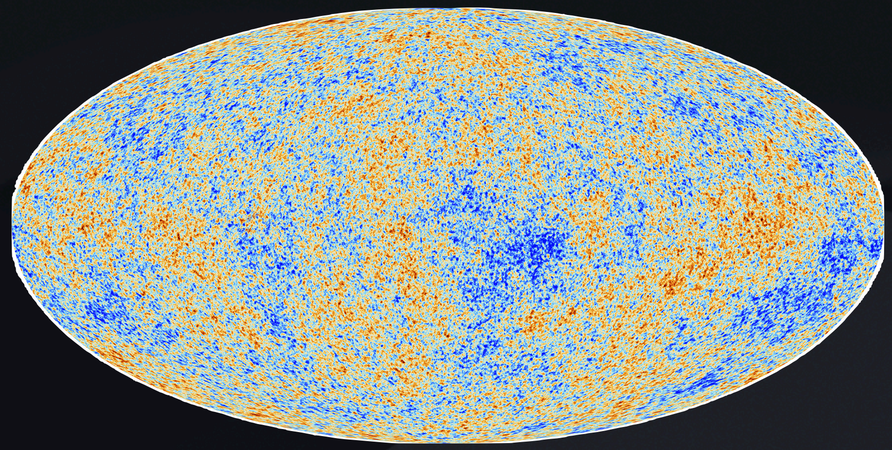
Combine with three probes

Baryon Acoustic Oscillations (BAO from SDSS)



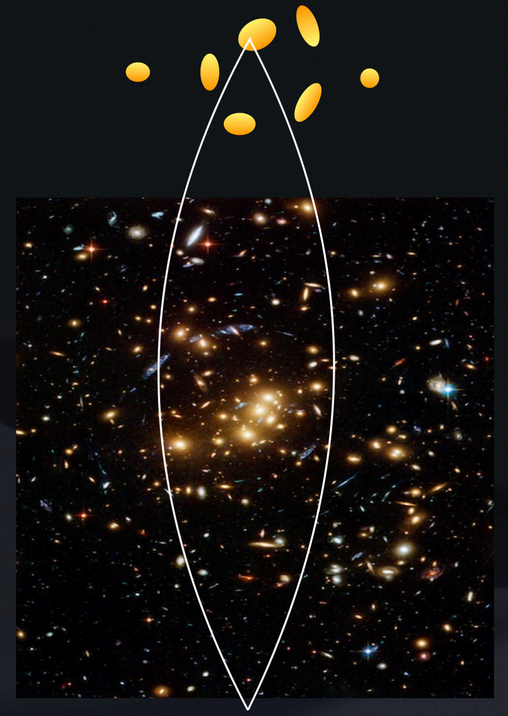
Alam et al. 2021;

Cosmic Microwave Background (CMB from Planck)



Planck 2020;

Two by three-point correlations (3x2pt from DES)



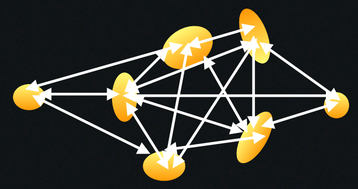
DES 2023

“Three by two point”

3 two-point correlations

“Three by two point”

3 two-point correlations

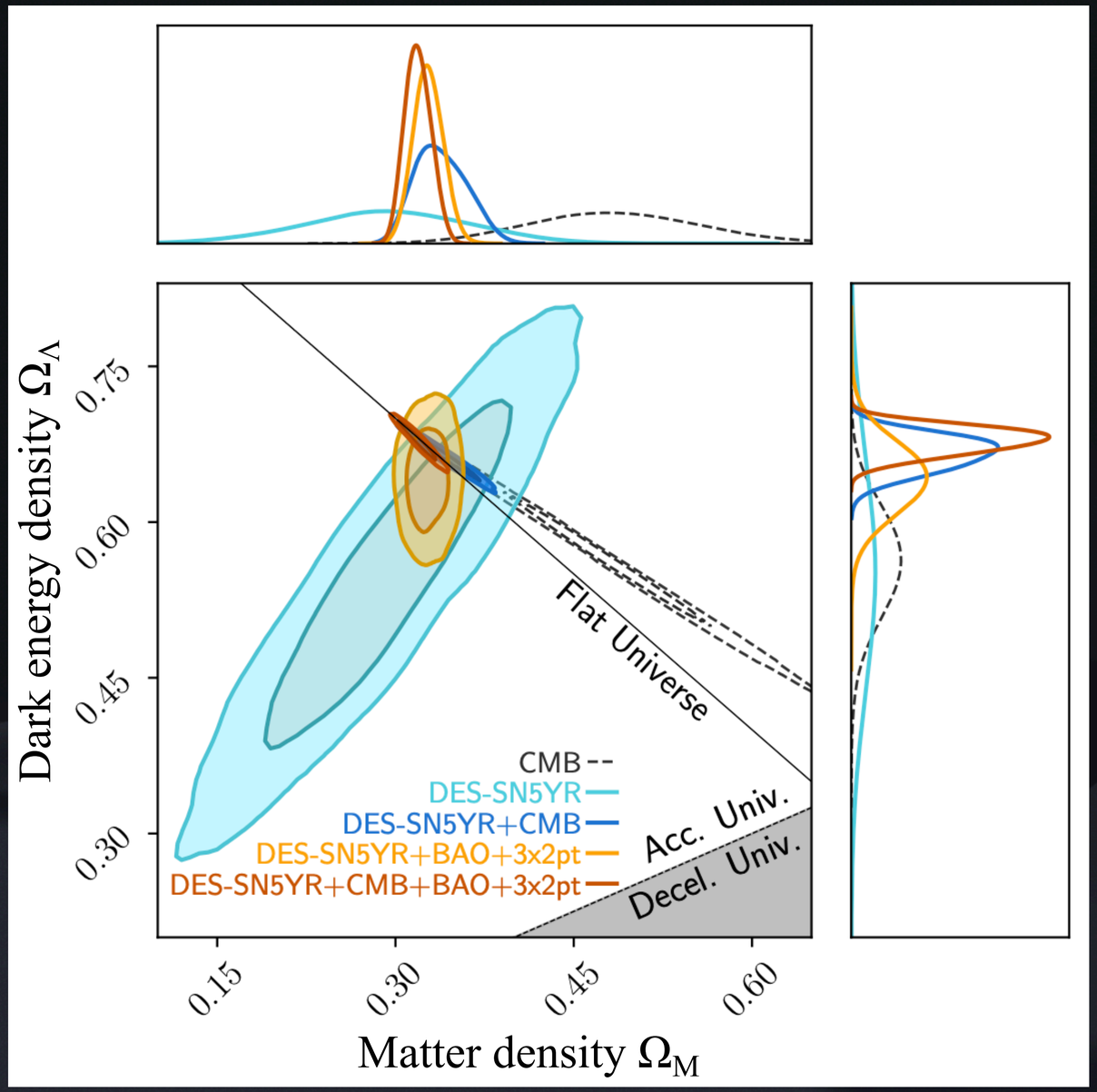


galaxy-galaxy

galaxy-lens

lens-lens

DES SN Cosmology Results: ΛCDM



DES-SN alone

$\Omega_M = 0.291^{+0.063}_{-0.065}$

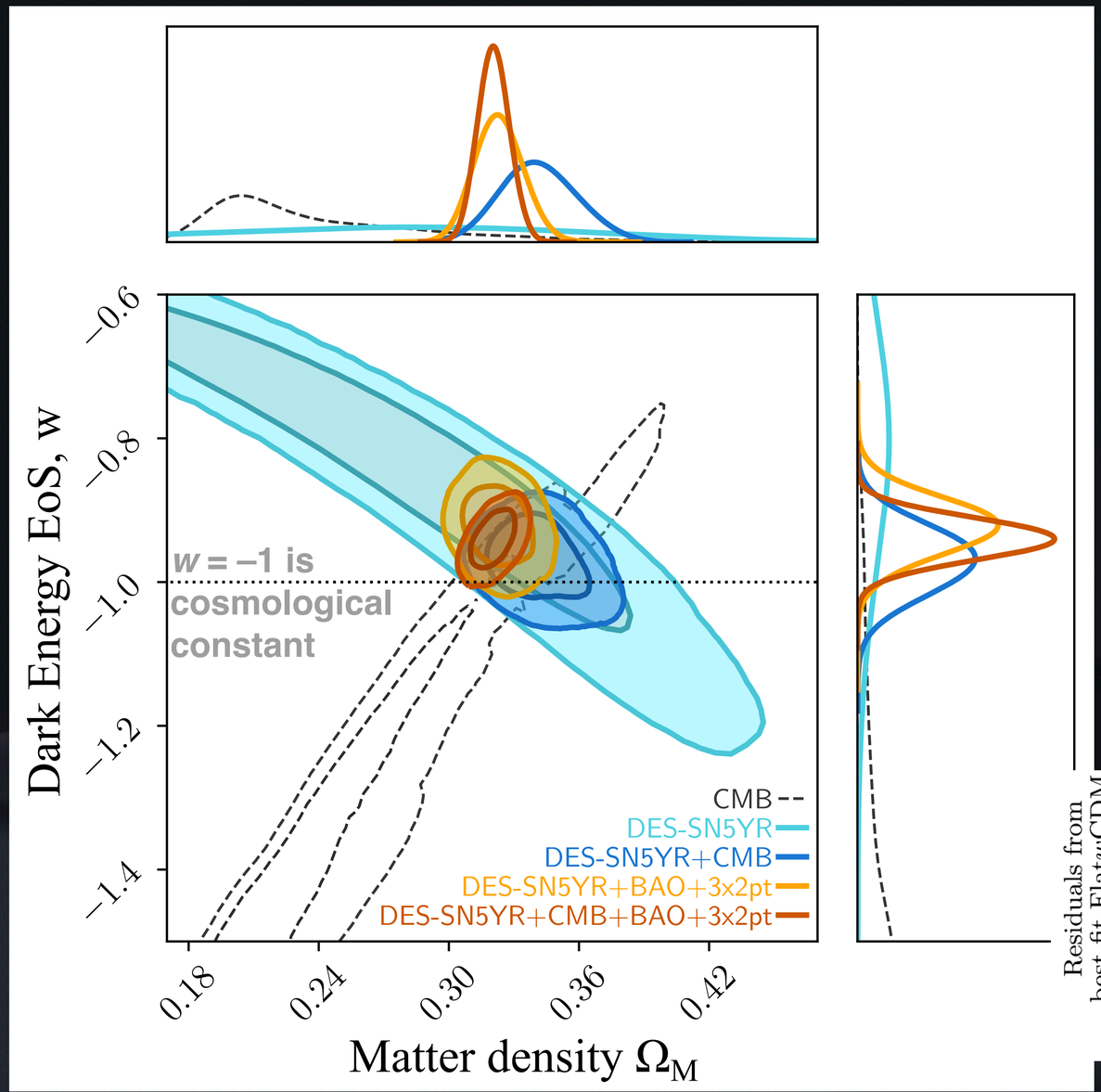
$\Omega_k = 0.16 \pm 0.16$

DES5YR + CMB + BAO + 3x2pt

$\Omega_M = 0.327^{+0.026}_{-0.032}$

$\Omega_k = 0.010 \pm 0.005$

DES SN Cosmology Results: wCDM

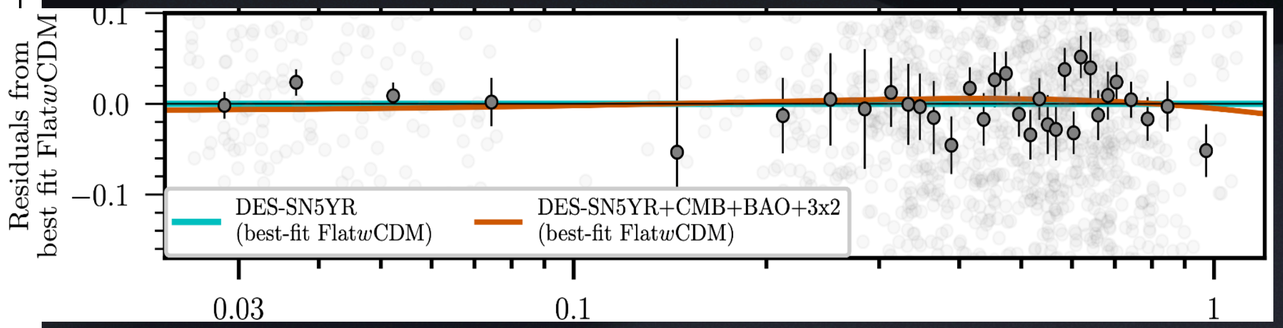


DES-SN alone

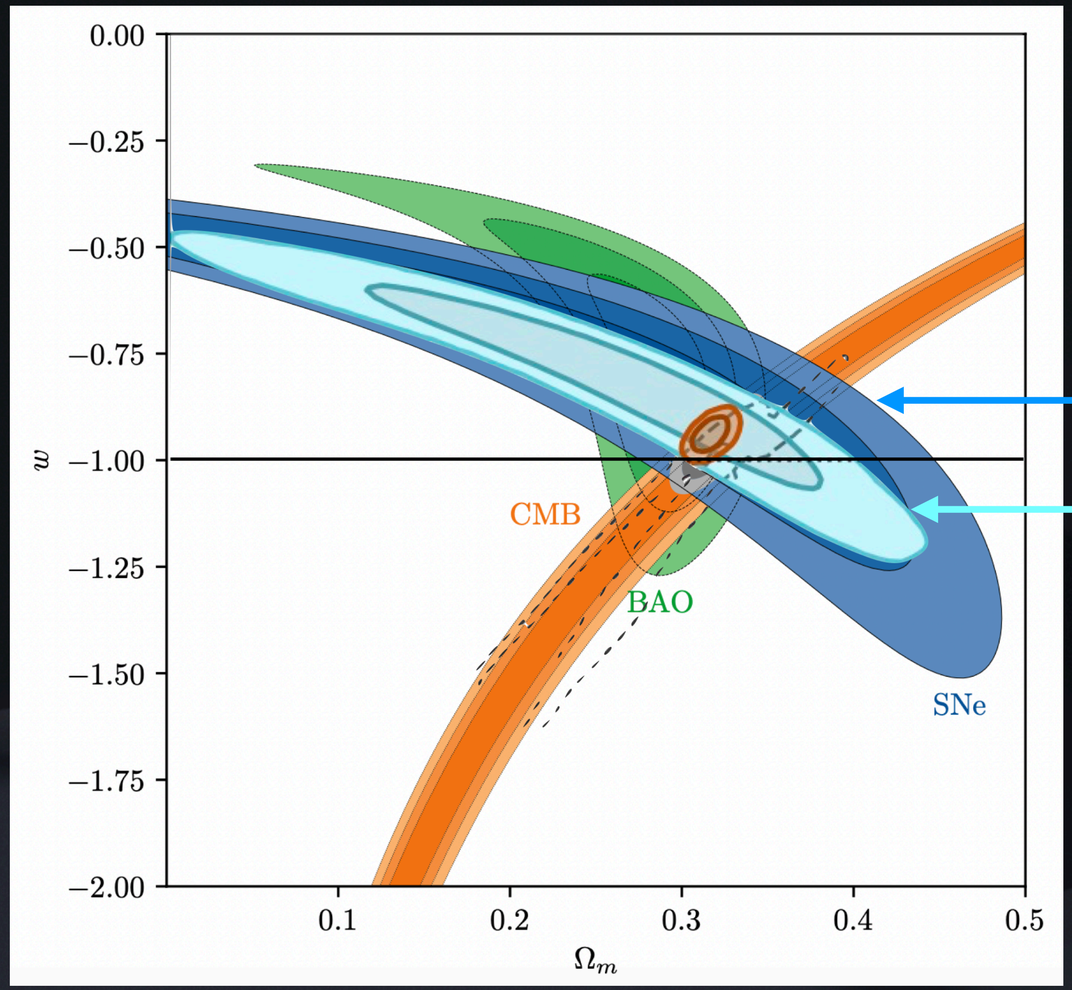
$w = -0.80^{+0.14}_{-0.16}$

DES5YR + CMB + BAO + 3x2pt

$w = -0.941 \pm 0.026$



Supernova data sets agree



Union3 (compilation of 2087 SNe from 24 data sets)

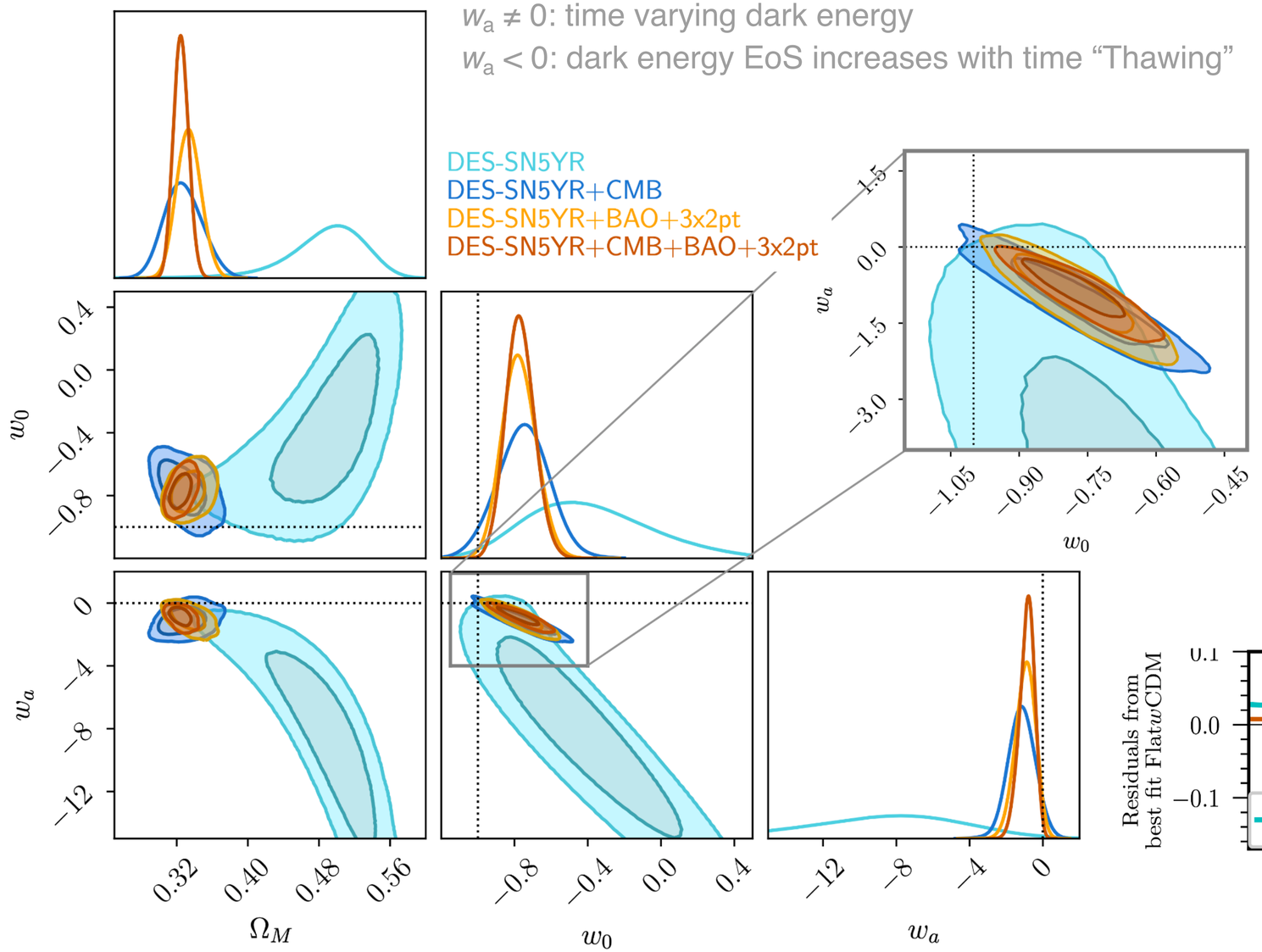
DES (1635 high-z SNe from DES
+ 194 low-z from 4 data sets)

DES SN Cosmology Results: w_0w_aCDM

$w=w_0+w_a(1-a)$

$w_a \neq 0$: time varying dark energy

$w_a < 0$: dark energy EoS increases with time “Thawing”

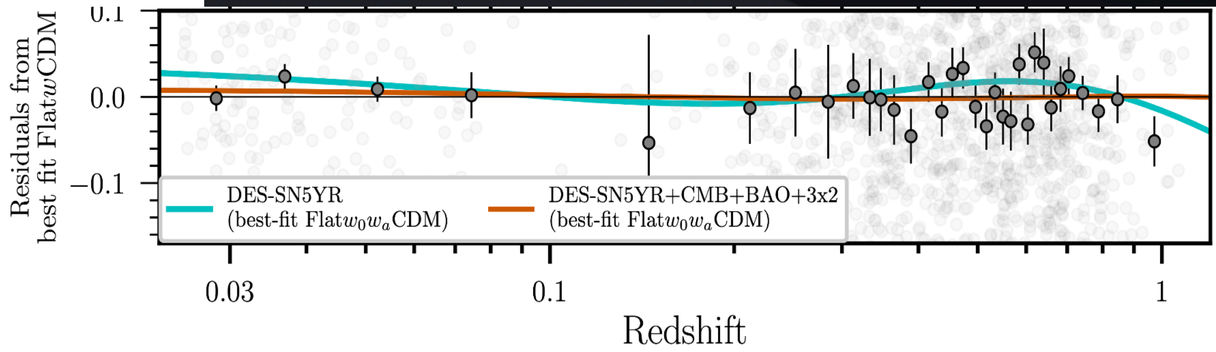


DES-SN alone

$w_a = -8.8^{+3.7}_{-4.5}$ (>2σ less than 0)

DES5YR + CMB + BAO + 3x2pt

$w_a = -0.83^{+0.33}_{-0.42}$ (>2 less than 0)



Paper published last week!

(Was accepted in March.)

THE ASTROPHYSICAL JOURNAL LETTERS

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The Dark Energy Survey: Cosmology Results with ~1500 New High-redshift Type Ia Supernovae Using the Full 5 yr Data Set

DES Collaboration: T. M. C. Abbott[1], M. Acevedo[2], M. Aguena[3], A. Alarcon[4], S. Allam[5], O. Alves[6], A. Amon[7], F. Andrade-Oliveira[6], J. Annis[5], P. Armstrong[8] Show full author list

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The Astrophysical Journal Letters, Volume 973, Number 1

Citation DES Collaboration: T. M. C. Abbott *et al* 2024 *ApJL* **973** L14

DOI 10.3847/2041-8213/ad6f9f

Article PDF Article ePub

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ober 1

Abstract

We present cosmological constraints from the sample of Type Ia supernovae (SNe Ia) discovered and measured during the full 5 yr of the Dark Energy Survey (DES) SN program. In contrast to most previous cosmological samples, in which SNe are classified based on their spectra, we classify the DES SNe using a machine learning algorithm applied to their light curves in four photometric bands. Spectroscopic redshifts are acquired from a dedicated follow-up survey of the host galaxies. After accounting for the likelihood of each SN being an SN Ia, we find 1635 DES SNe in the redshift range $0.10 < z < 1.13$ that pass quality selection criteria sufficient to constrain cosmological parameters. This quintuples the number of high-quality $z > 0.5$ SNe compared to the previous leading compilation of Pantheon+ and results in the tightest cosmological constraints achieved by any SN data set to date. To derive cosmological constraints, we combine the DES SN data with a high-quality external low-redshift sample consisting of 194 SNe Ia spanning $0.025 < z < 0.10$. Using SN data alone and including systematic uncertainties, we find $\Omega_{\rm M} = 0.352 \pm 0.017$ in flat ΛCDM. SN data alone now require acceleration ($q_0 < 0$ in ΛCDM) with over 5σ confidence. We find $(\Omega_{\rm M}, w) = (0.264^{+0.074}_{-0.096}, -0.80^{+0.14}_{-0.16})$ in flat wCDM. For flat w_0w_aCDM, we find $(\Omega_{\rm M}, w_0, w_a) = (0.495^{+0.033}_{-0.043}, -0.36^{+0.36}_{-0.30}, -8.8^{+3.7}_{-4.5})$, consistent with a constant equation of state to within

Data are public

All DES data and code: https://github.com/des-science/DES-SN5YR

OzDES spectra: https://docs.datacentral.org.au/ozdes/

des-sn-dr.readthedocs.io/en/latest/

Table of Contents

Next topic

0 - DATA: Transient light

Dark Energy Survey Supernova Program 5YR

The DES Supernova Program 5-year Data release.

The Dark Energy Survey Supernova Program (DES-SN) consisted on 5 years of observations using the Dark Energy Survey instrument, finding Type Ia Supernovae up to cosmological redshifts $z > 1.1$.

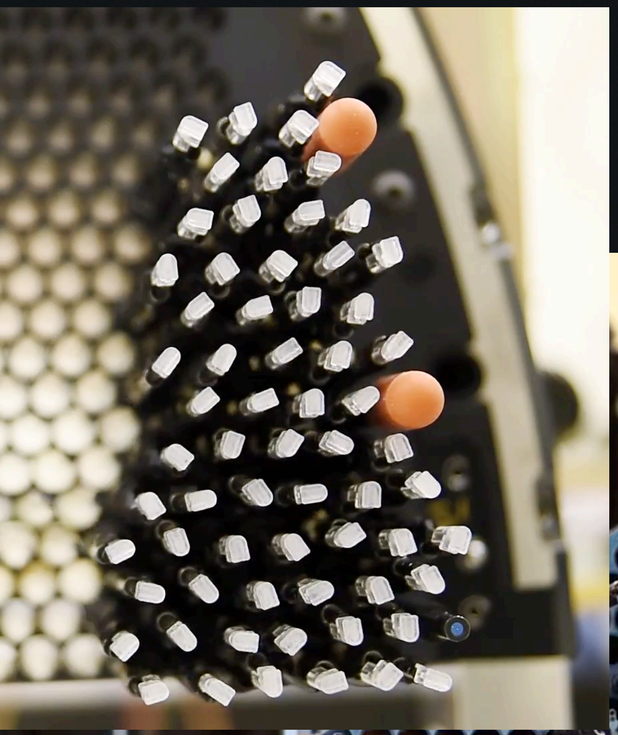
This is the **full public data release** of DES-SN (DES-SN5YR) containing all data products used to compute the cosmological result from the full 5 years of photometrically classified supernovae (SNe) combined with a sample of low-redshift SNe.

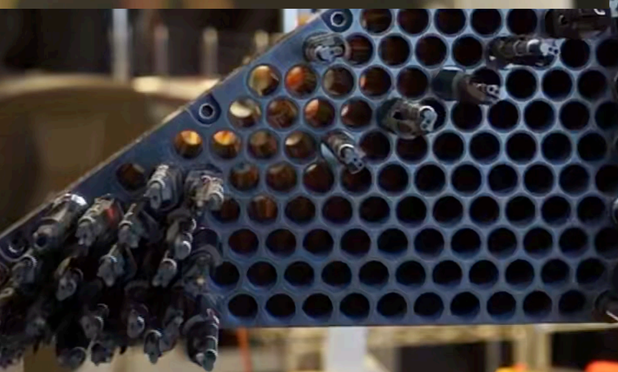
Instructions to download the full data release and its accompanying python utility package can be found below.

Detailed description of release Contents

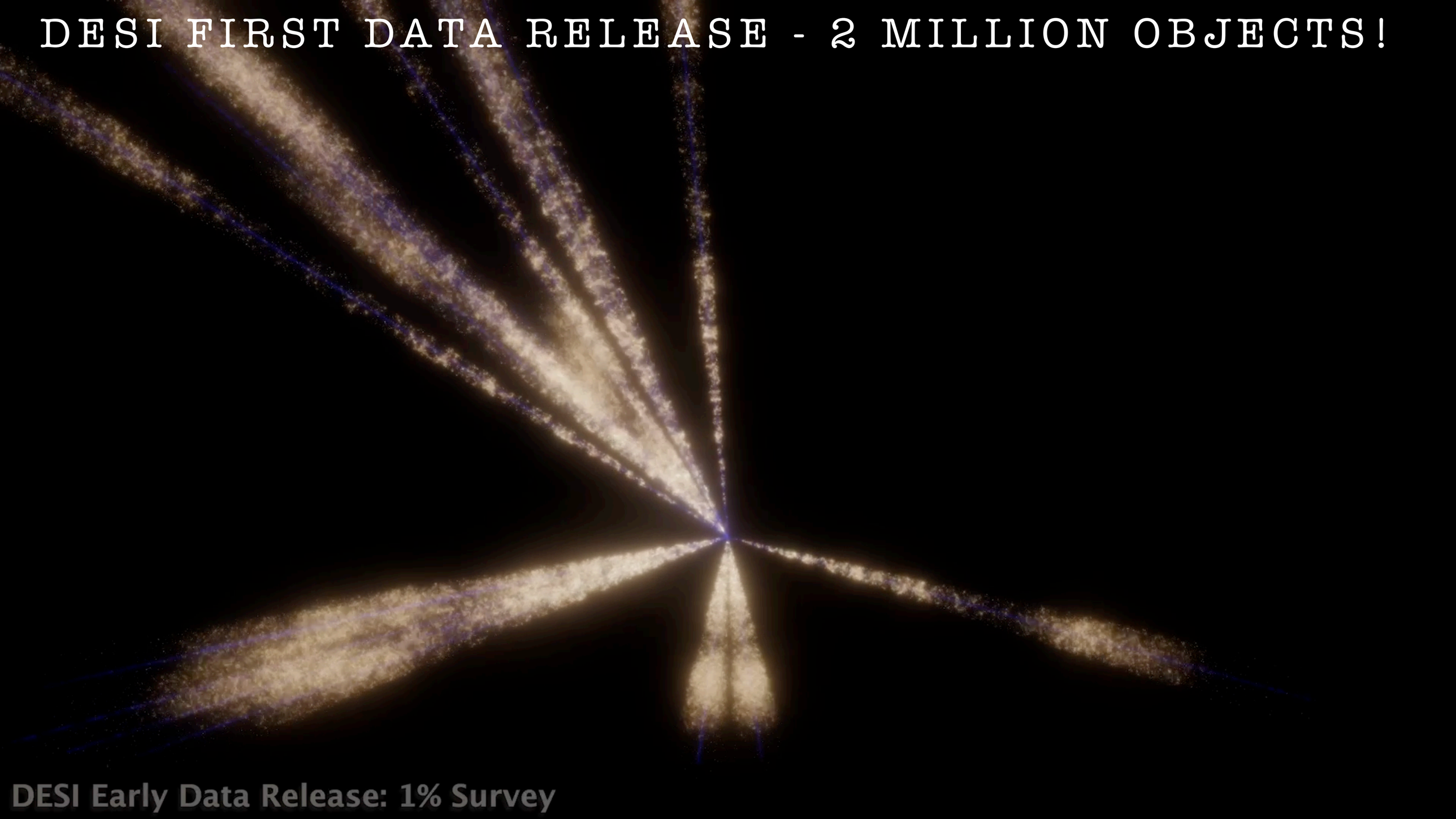
The Dark Energy Spectroscopic Instrument

DESI (different to DES!)



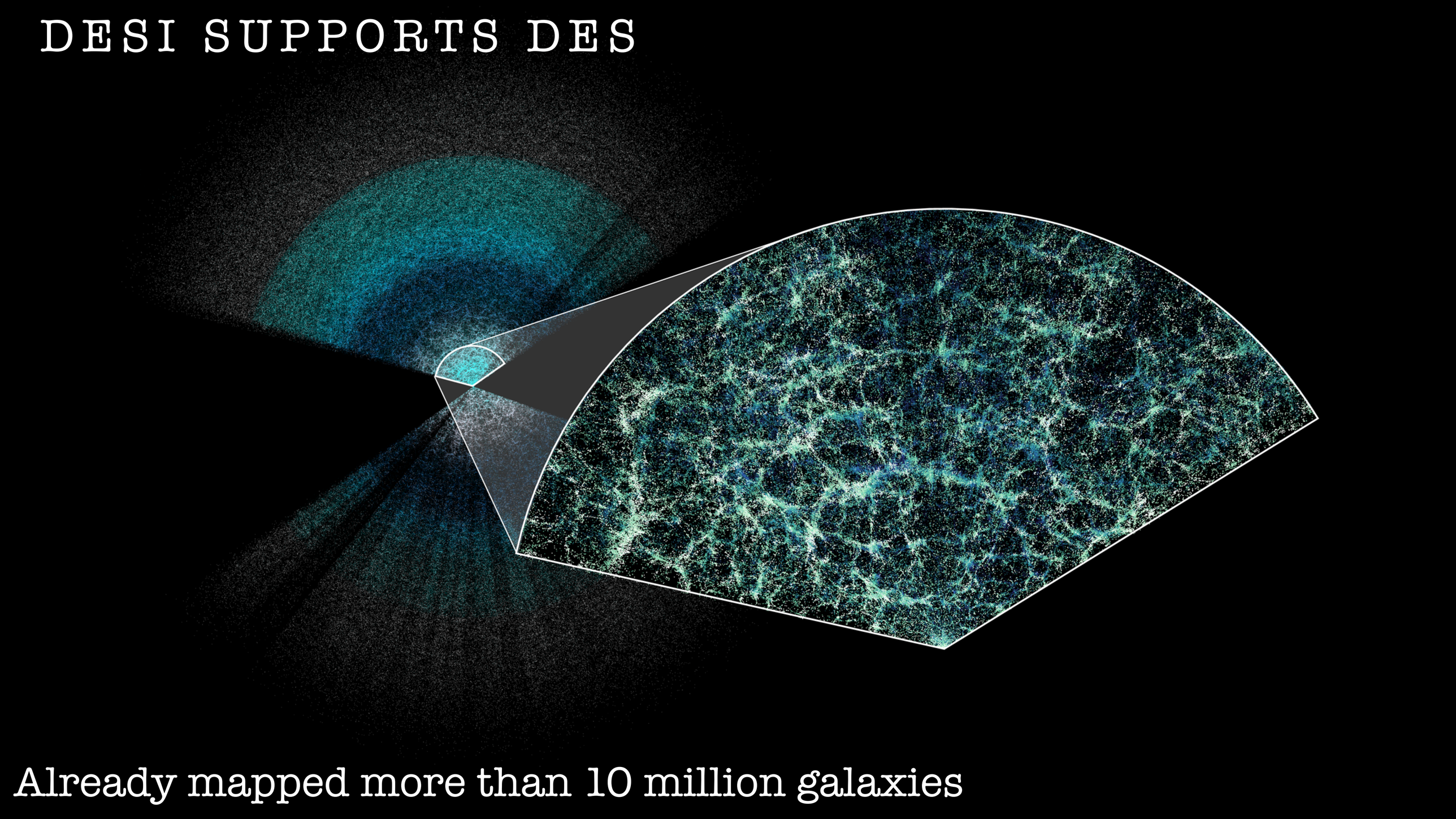


DESI FIRST DATA RELEASE - 2 MILLION OBJECTS!



DESI Early Data Release: 1% Survey

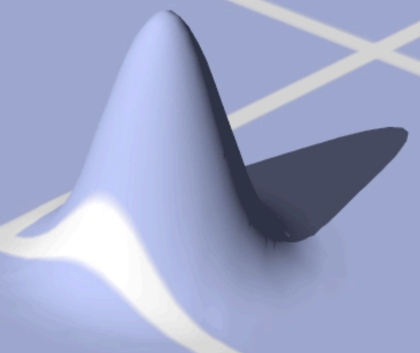
DESI SUPPORTS DES



Already mapped more than 10 million galaxies

Baryon Acoustic Oscillations (BAO)

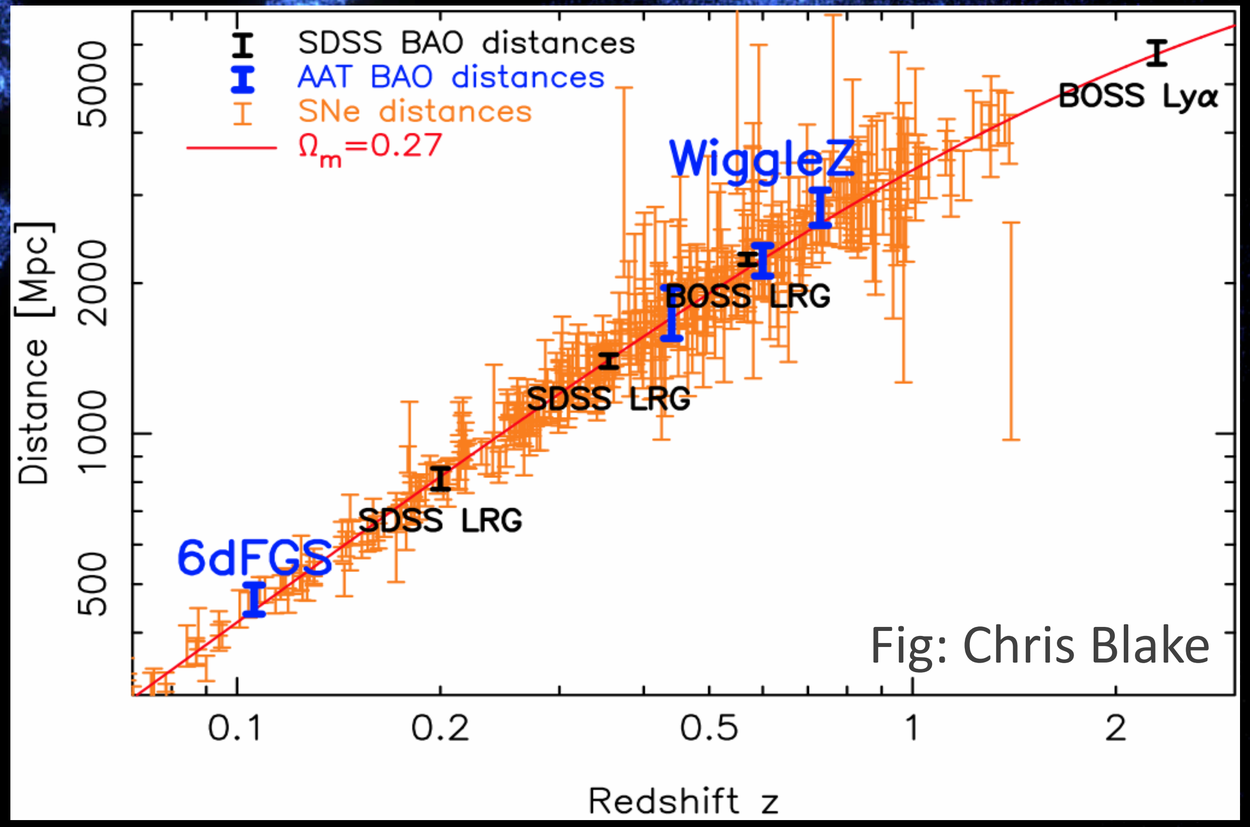
Independent technique



CAASTRO
ALL-SKY ASTROPHYSICS

Confirmation of Acceleration

WiggleZ BAO (2011)



DESI BAO measurements

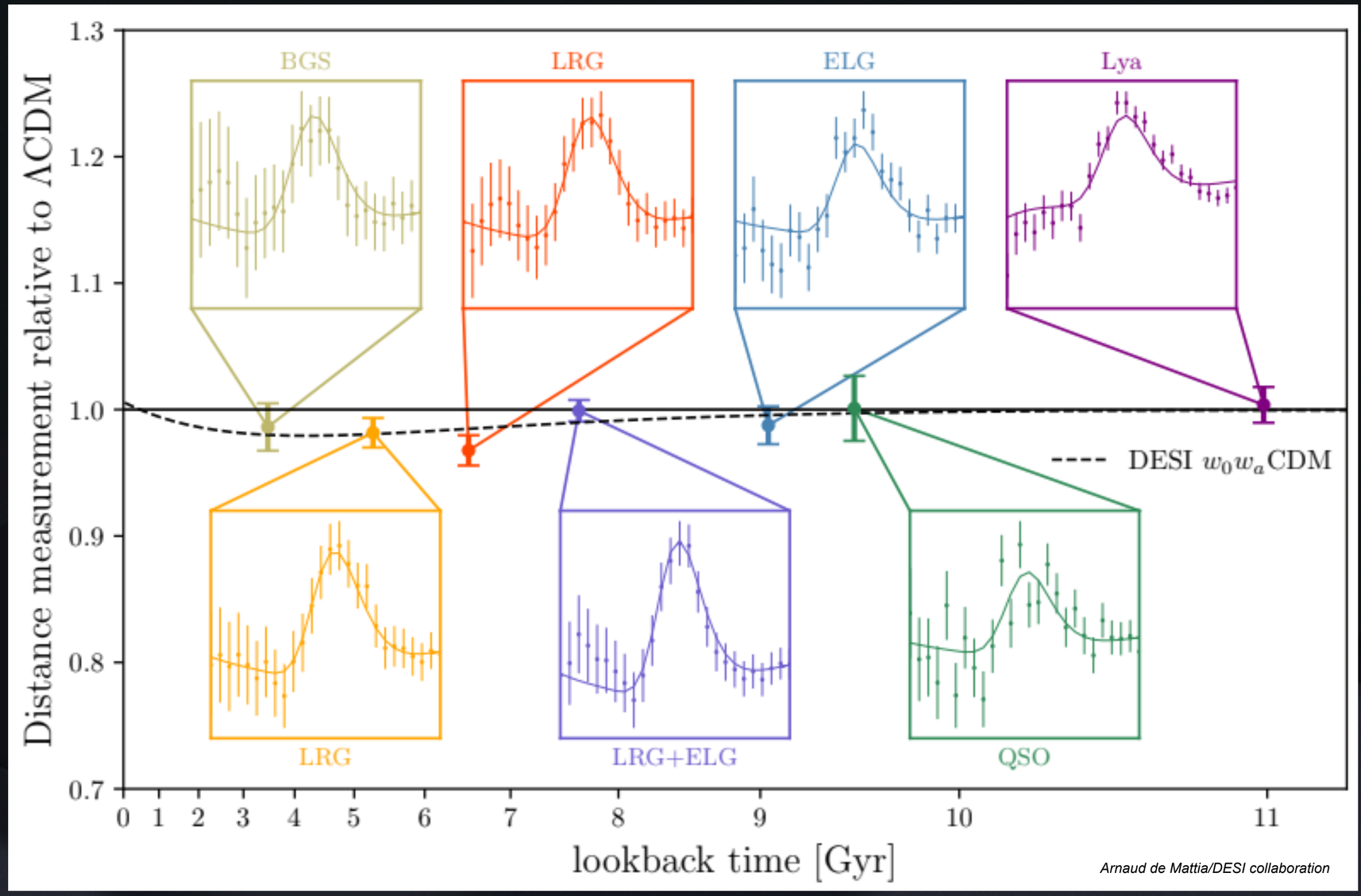
BGS = Bright Galaxy Survey

LRG = Luminous Red Galaxy

ELG = Emission Line Galaxy

QSO = Quasi Stellar Object

Lya = Lyman alpha forest



Arnaud de Mattia/DESI collaboration

DESI BAO m

BGS = Bright Galaxy Survey

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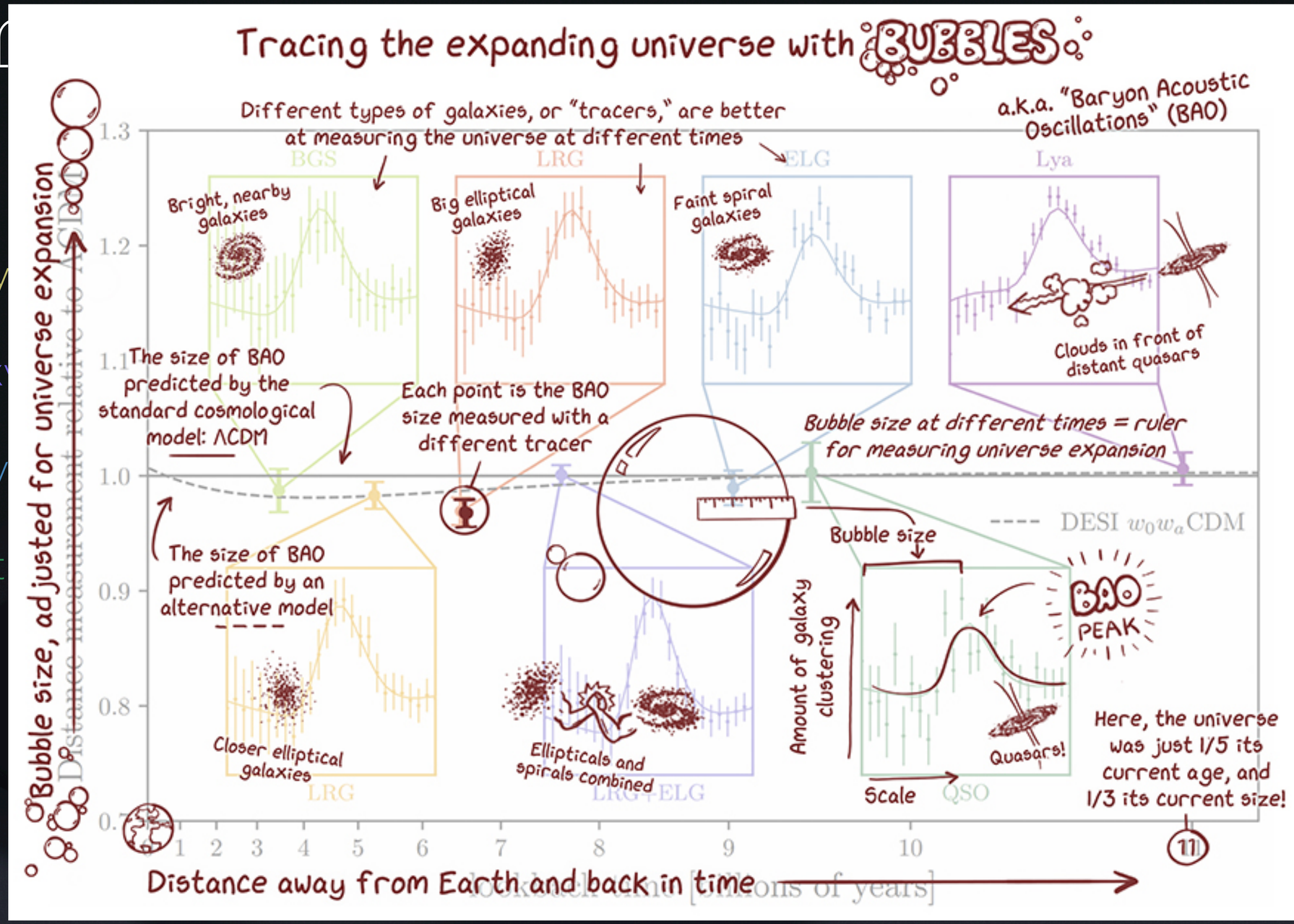
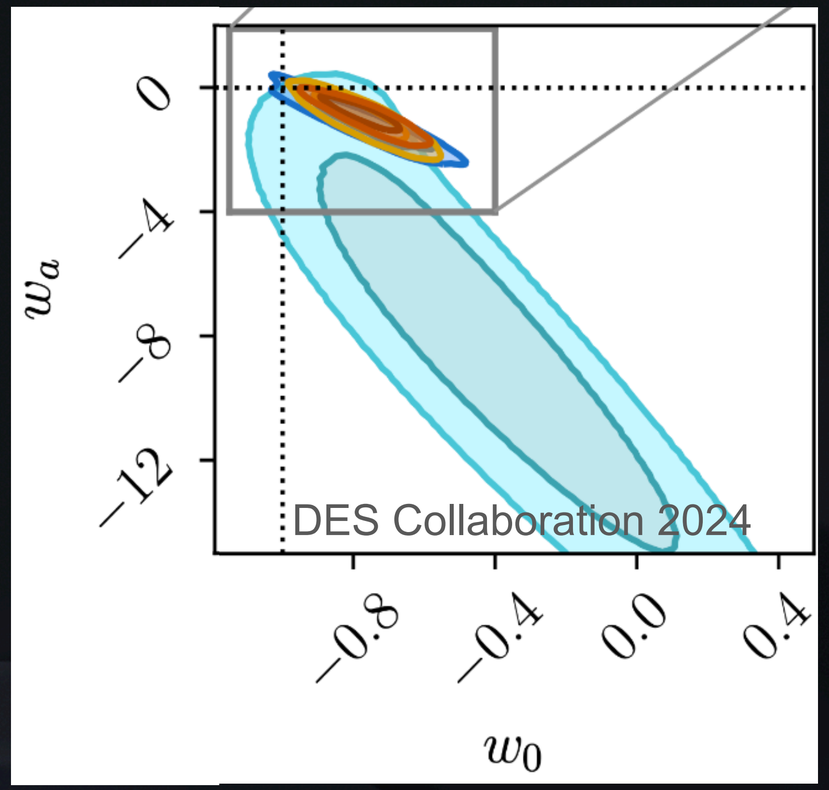
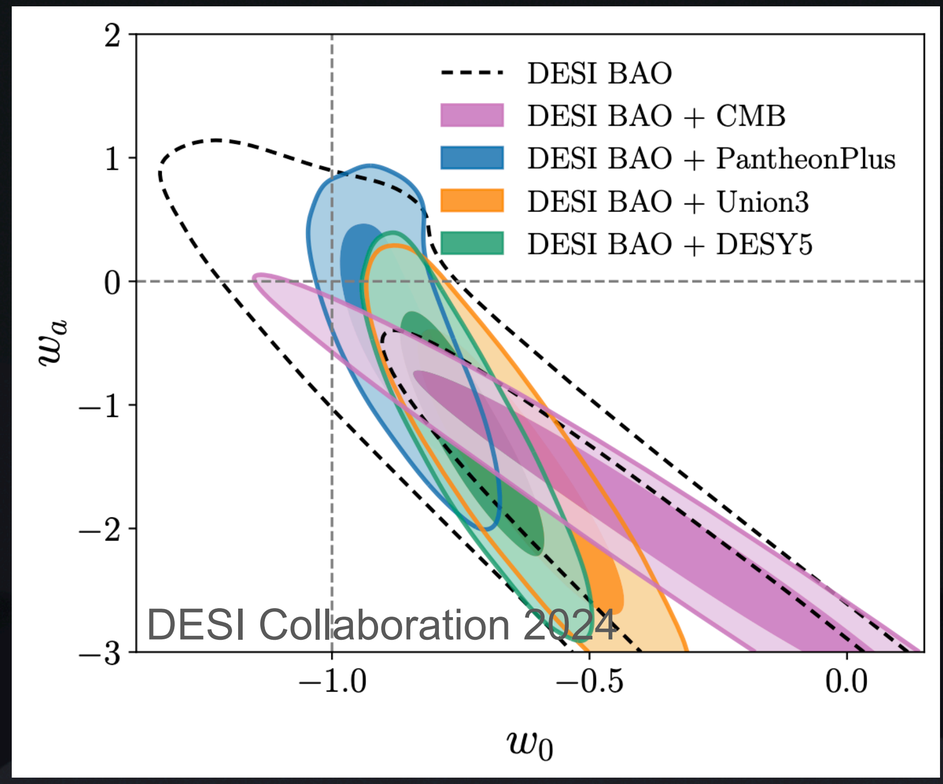


April 2024: DESI supports DES!

DESI finds similar result for w_a



DES: $w_a = -8.8^{+3.7}_{-4.5}$

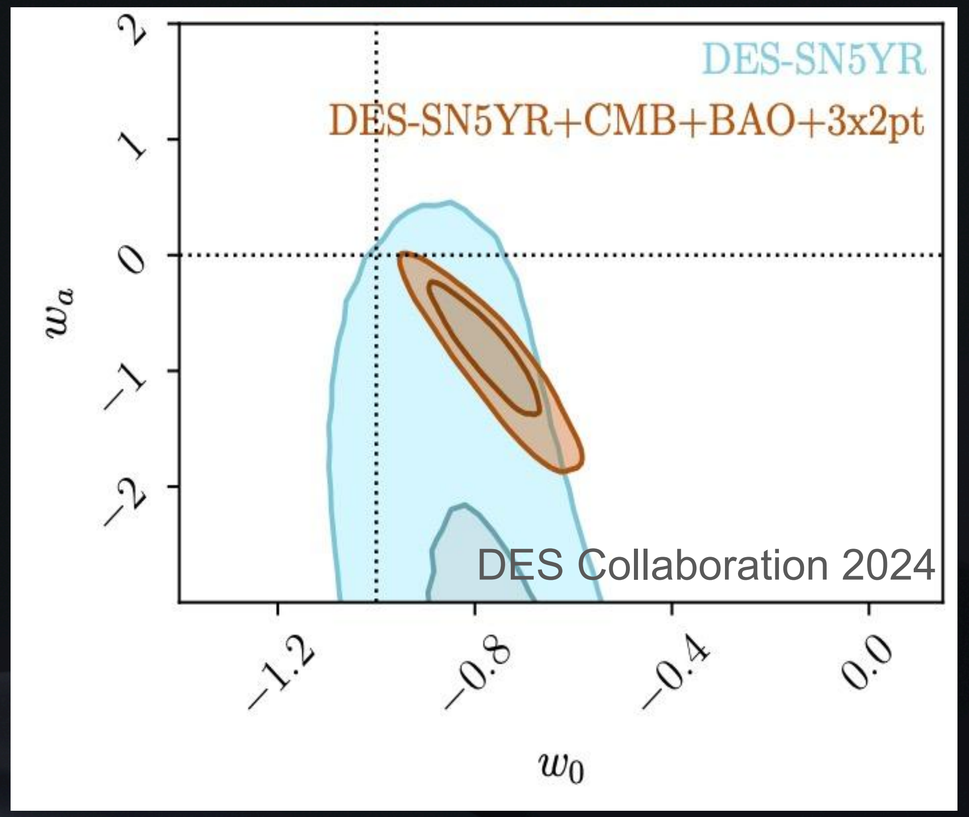


DESI: w_a < -1.32

DES+DESI+CMB: $w_a = -1.05^{+0.31}_{-0.27}$ **(>3 less than 0)**

April 2024: DESI supports DES!

DESI finds similar result for w_a



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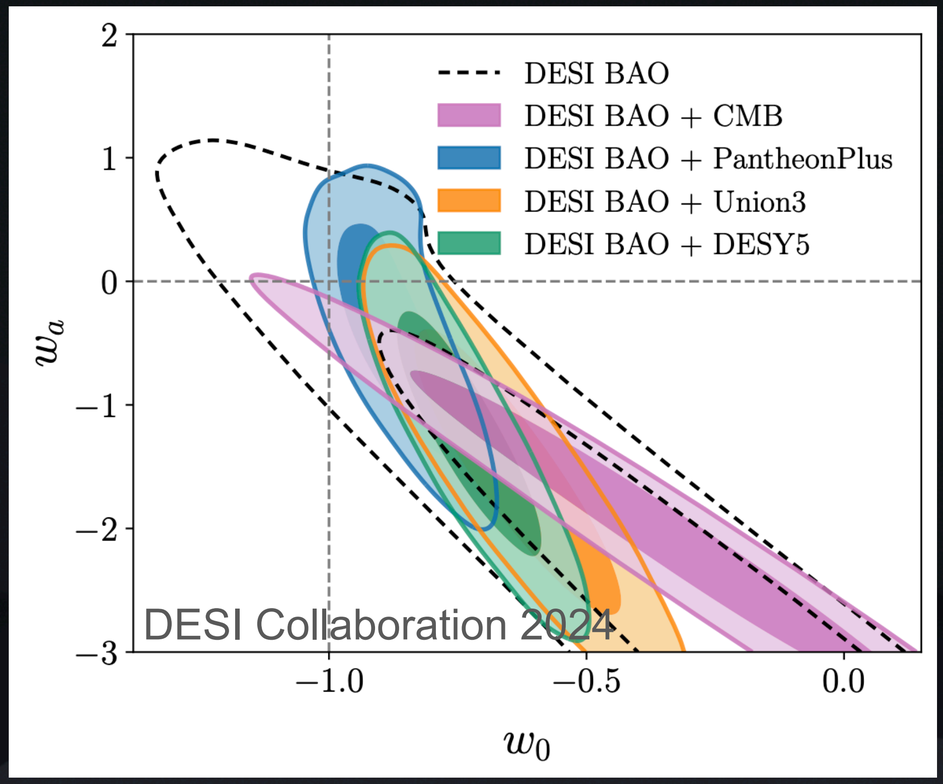

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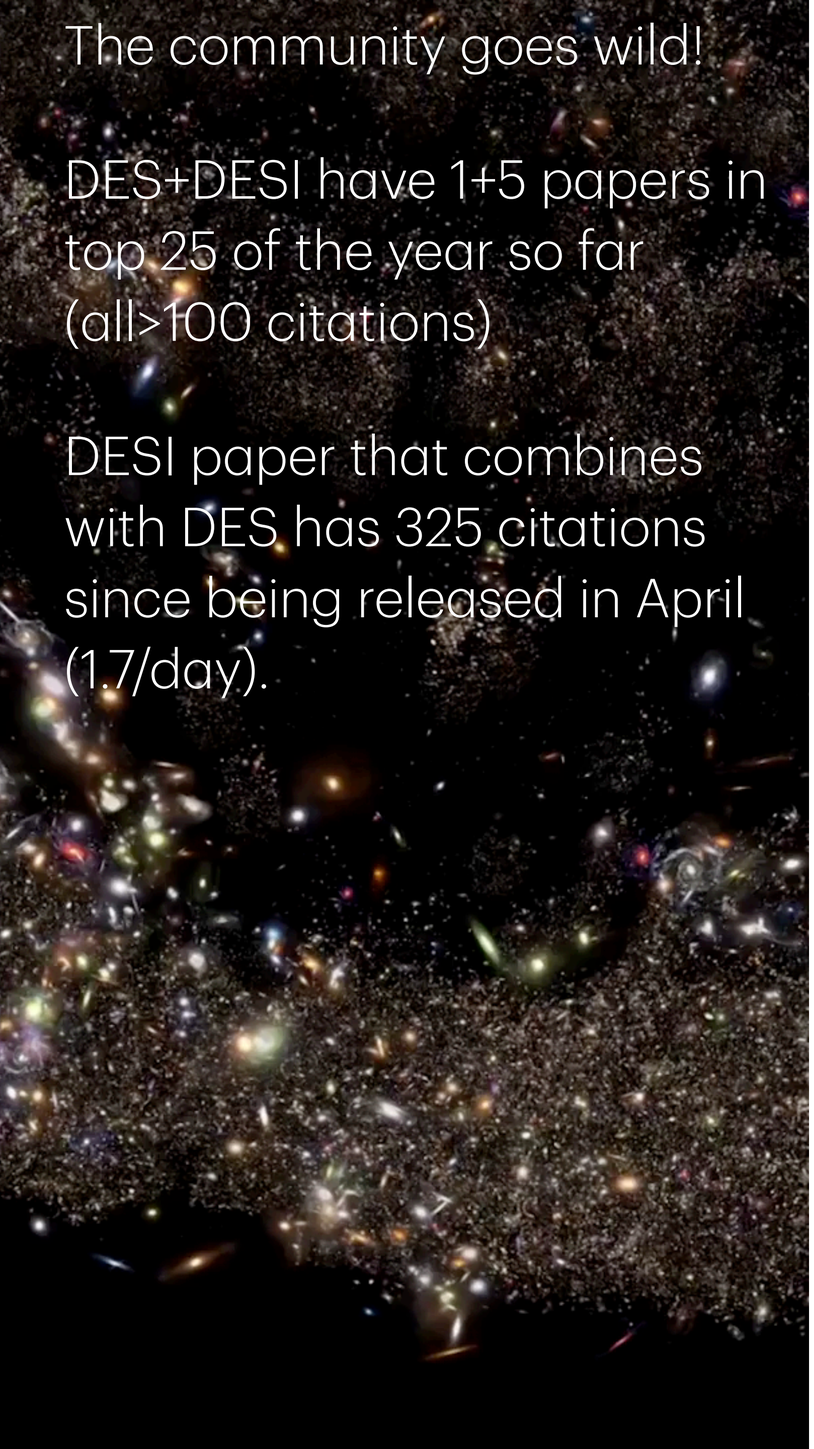


The community goes wild!

DES+DESI have 1+5 papers in top 25 of the year so far (all>100 citations)

DESI paper that combines with DES has 325 citations since being released in April (1.7/day).

The New York Times

Argh! I hate these kinds of headlines!!

A Tantalizing 'Hint' That Astronomers Got Dark Energy All Wrong

Scientists may have discovered a major flaw in their understanding of that mysterious cosmic force. That could be good news for the fate of the universe.

"**It may be the first real clue we have gotten about the nature of dark energy in 25 years,**" - Adam Riess

The Big Questions

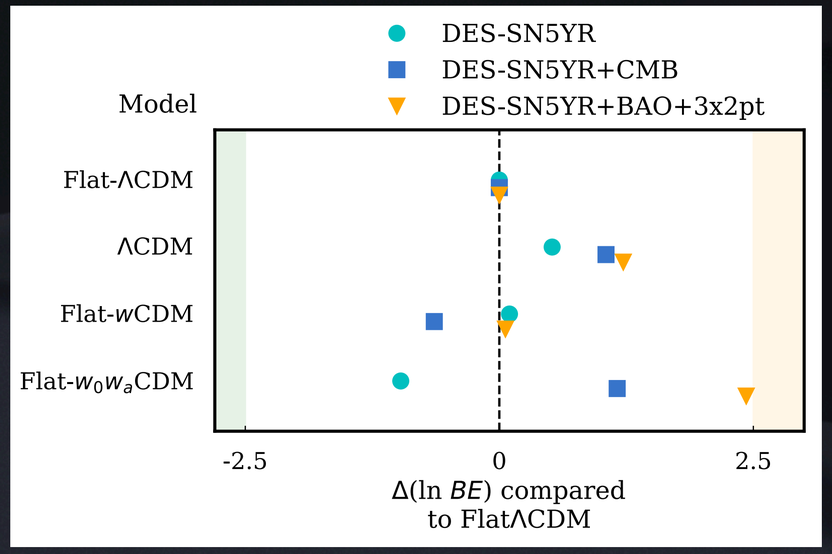
- Is the Universe accelerating?
- Is dark energy a cosmological constant?
- How old is the Universe?
- Does this solve the Hubble Tension?

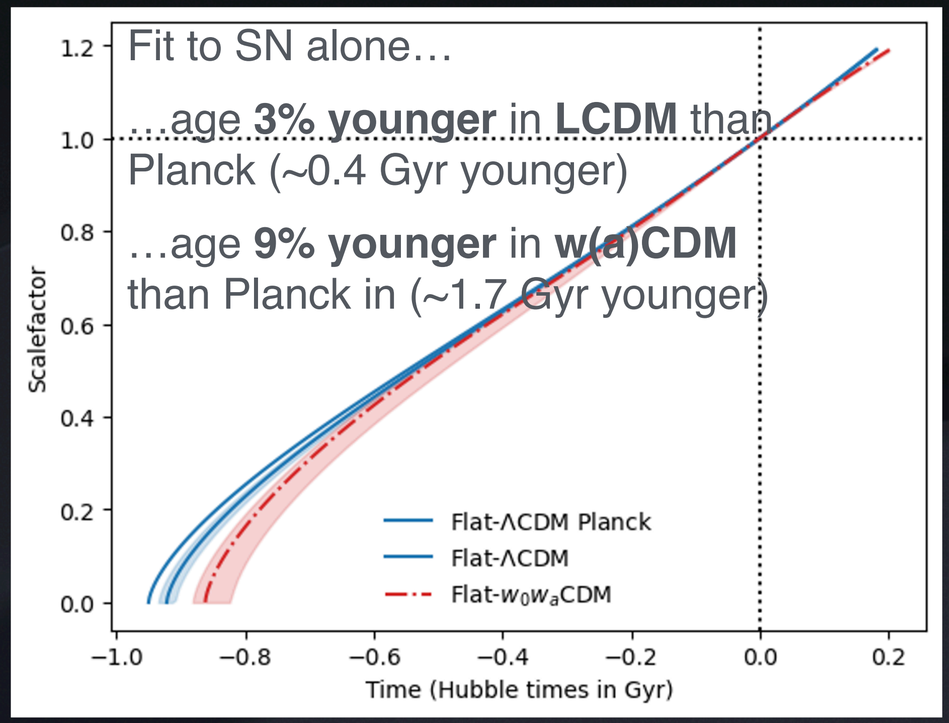
Yes!

Maybe… (but it's not the best fit)

Slightly younger than we thought?

No.

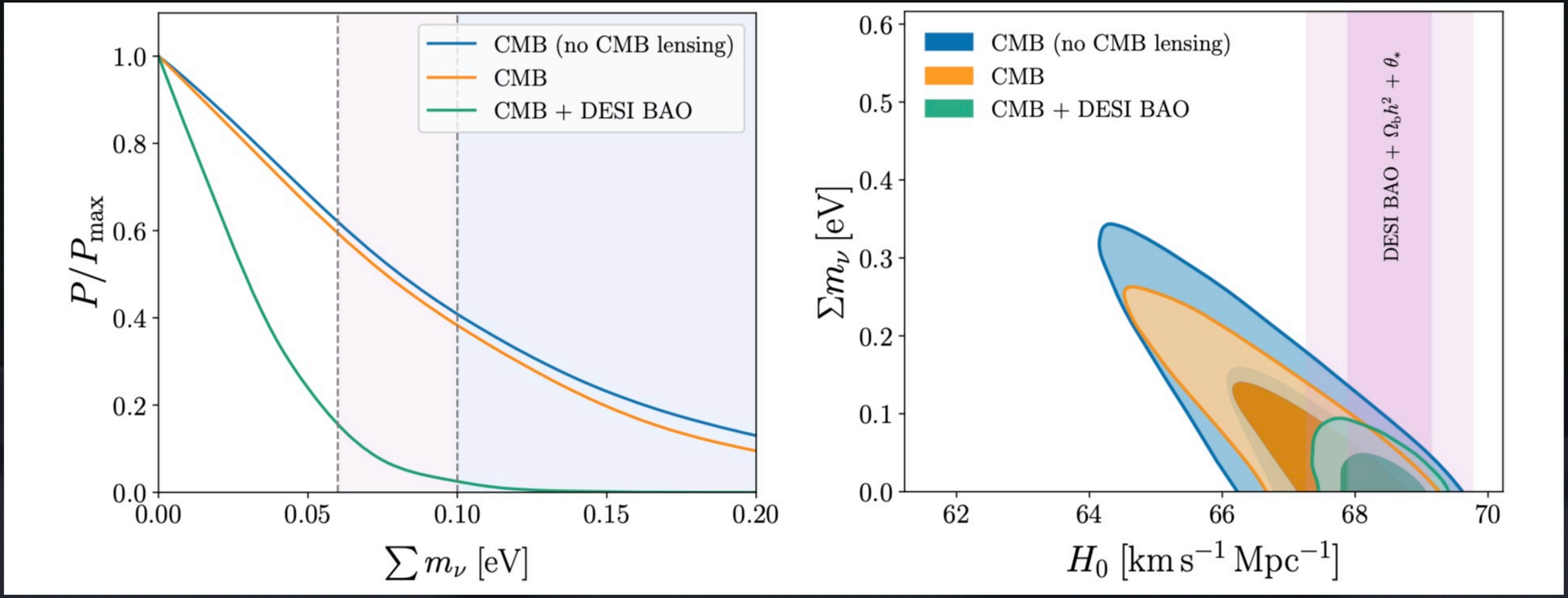




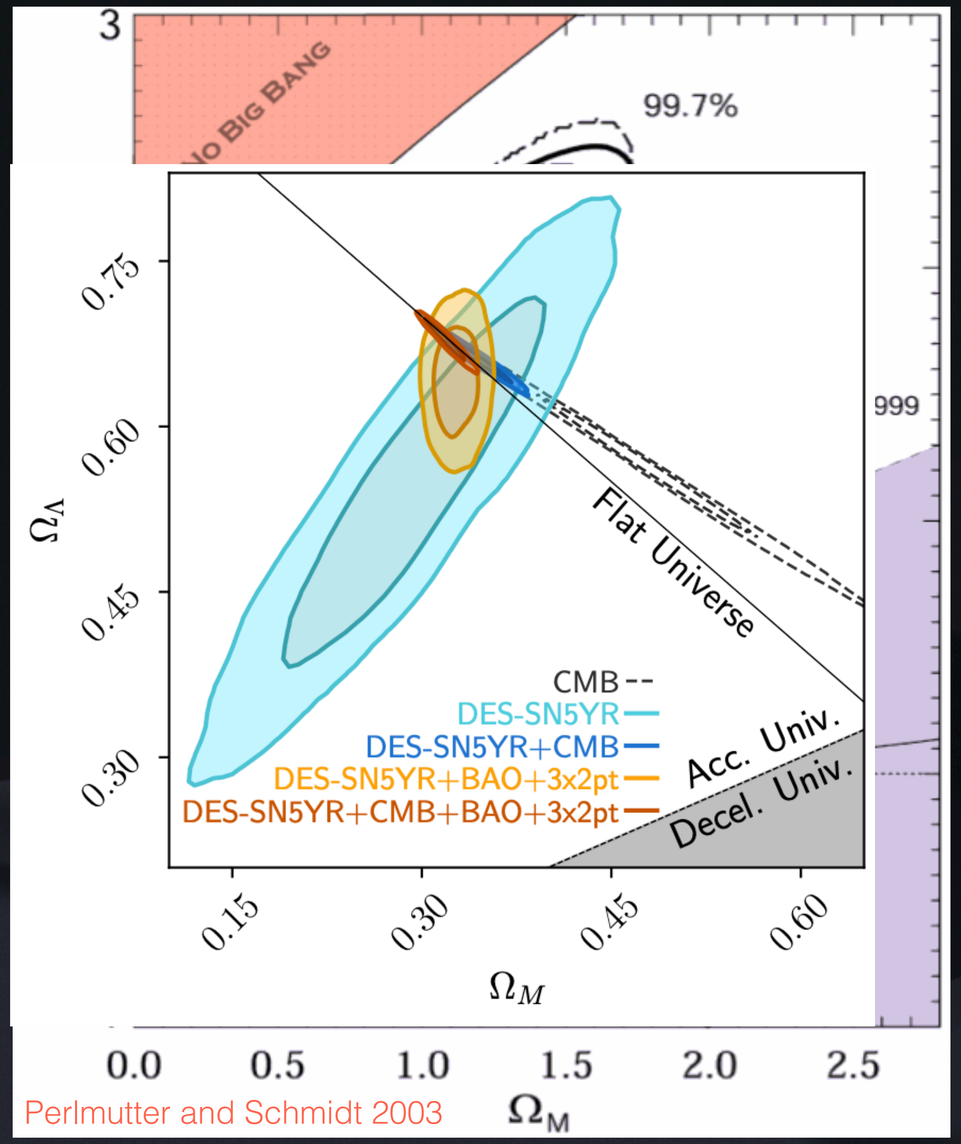
Neutrino tensions

LCDM+neutrinos

- 3 degenerate mass eigenstates with minimal prior $\sum m_\nu > 0$

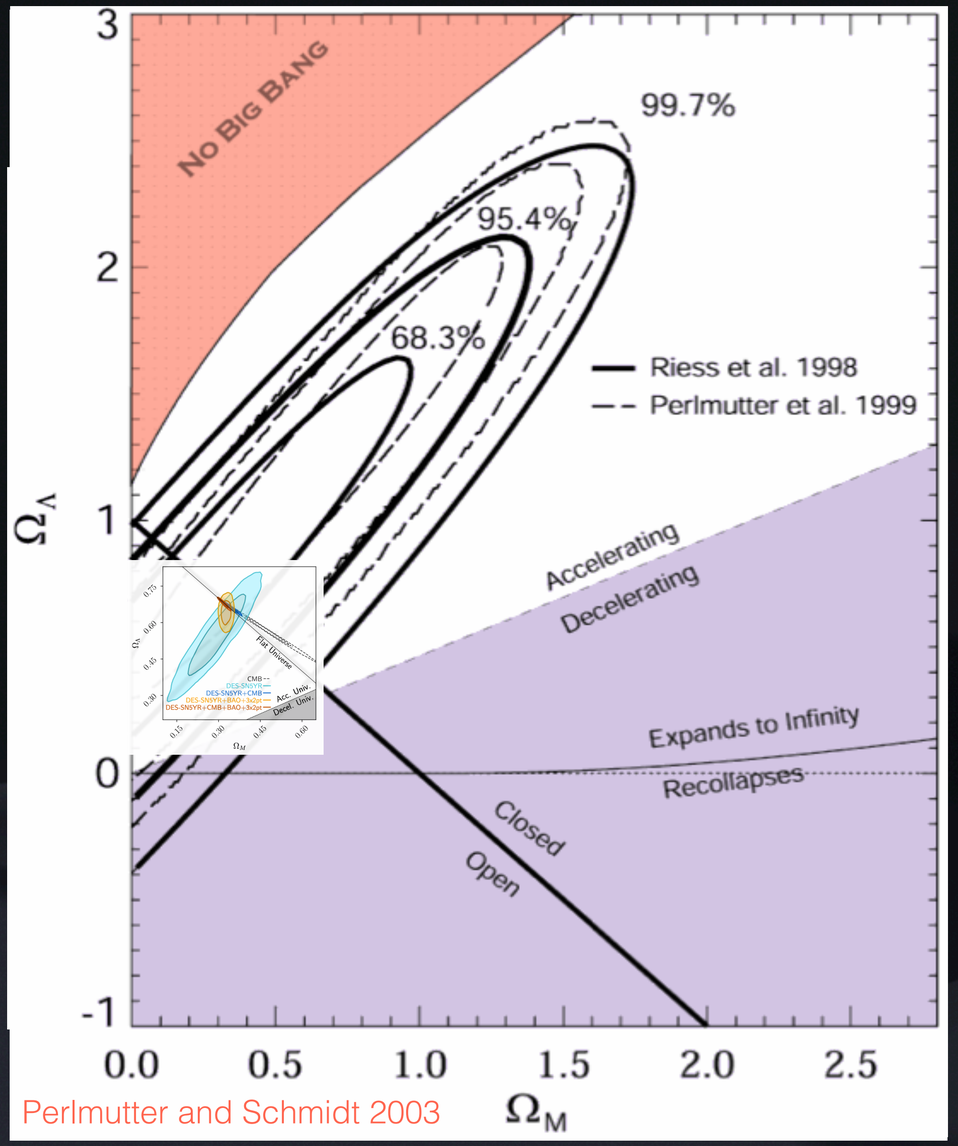


How far have we come?

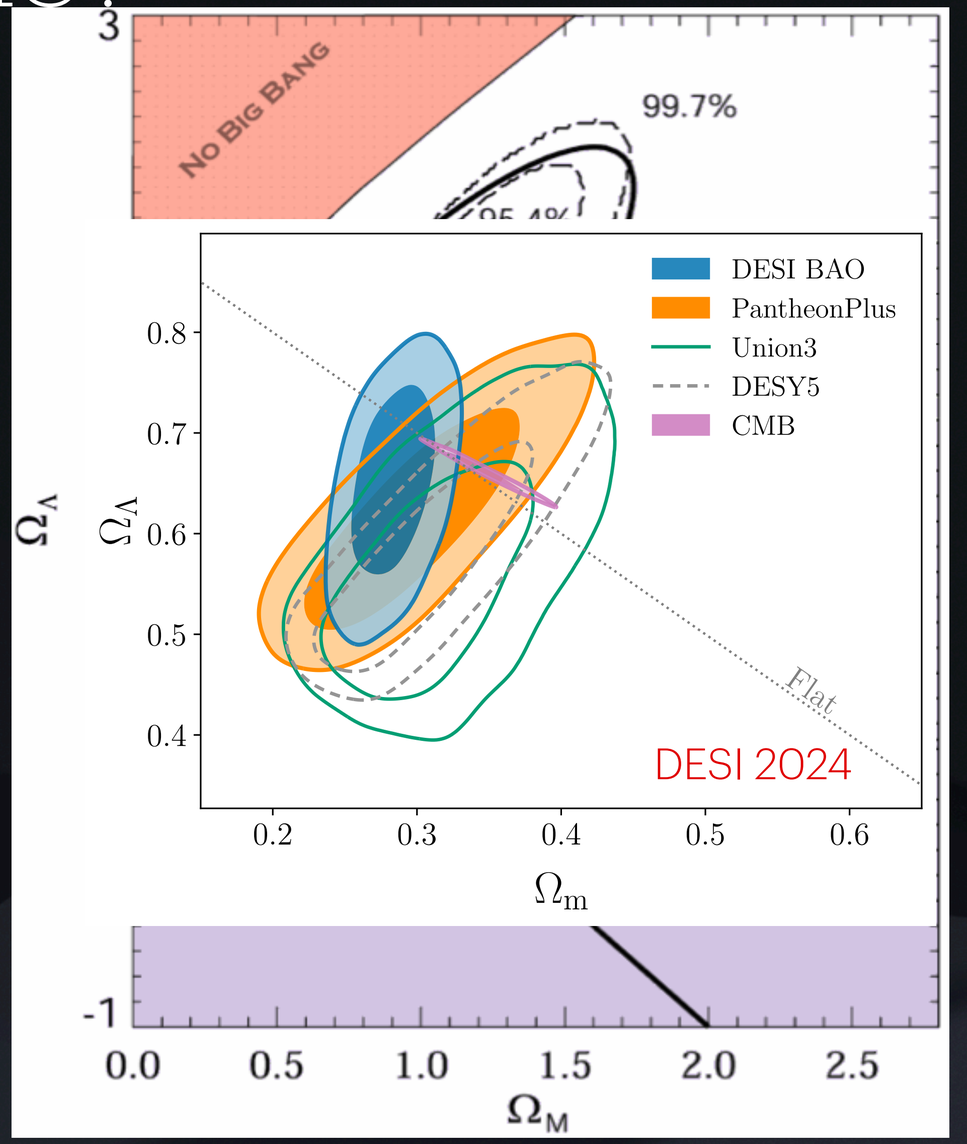


Perlmutter and Schmidt 2003

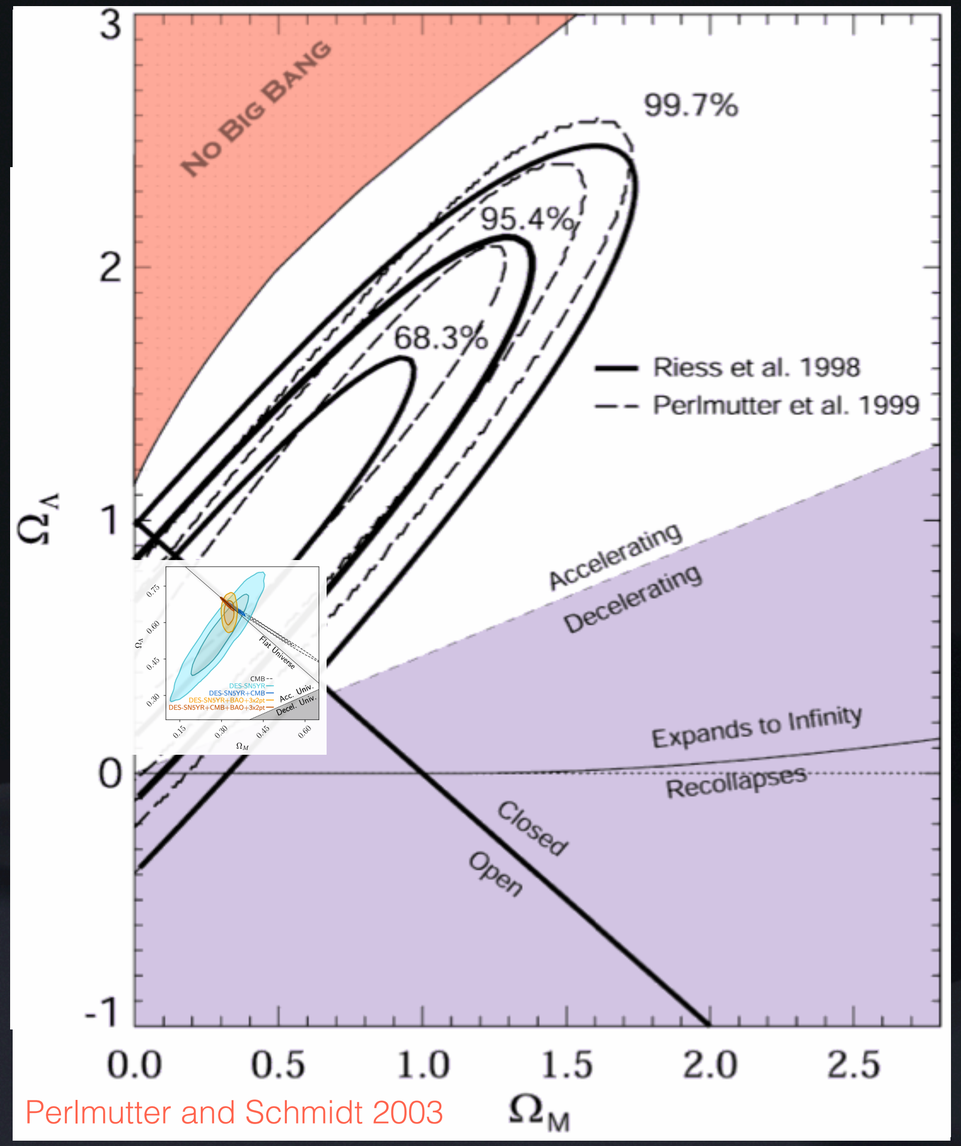
How far have we come?



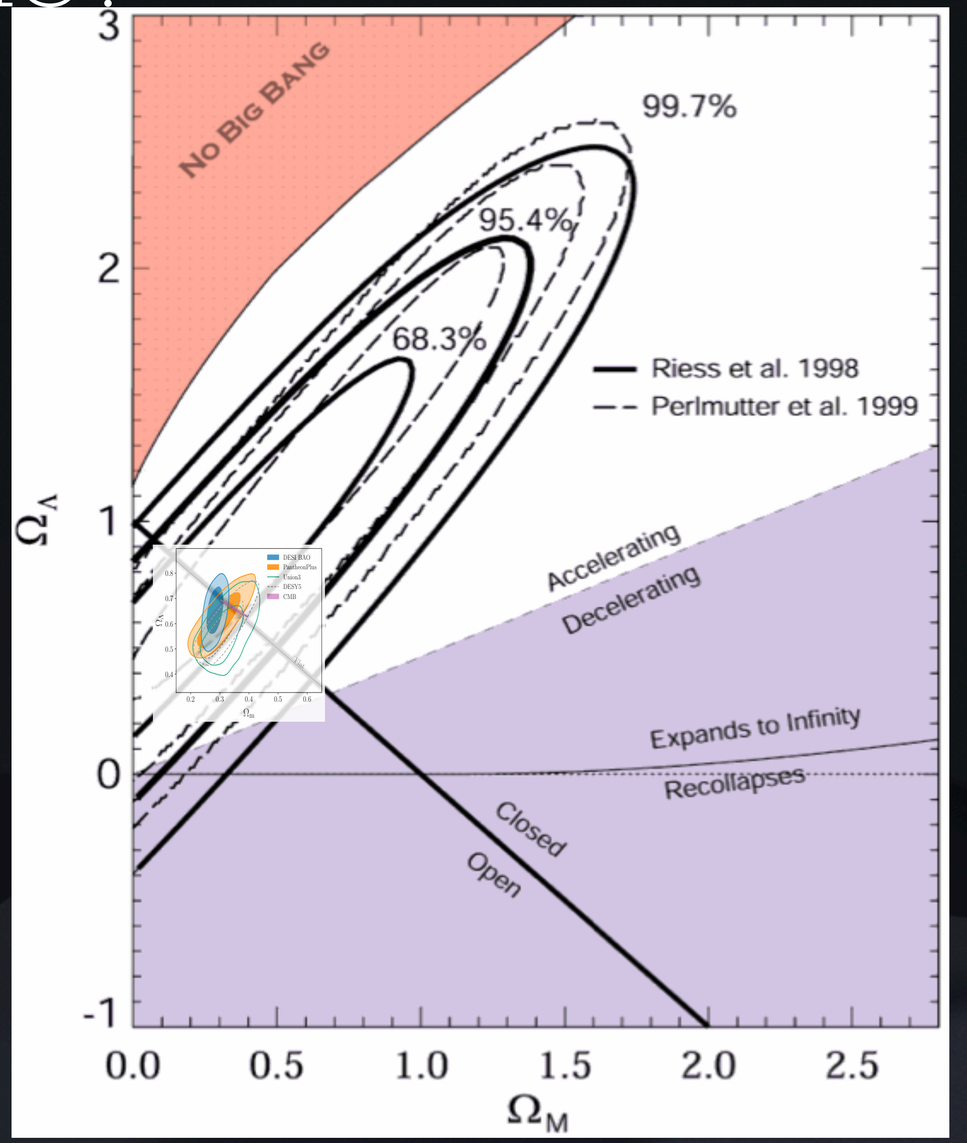
Perlmutter and Schmidt 2003



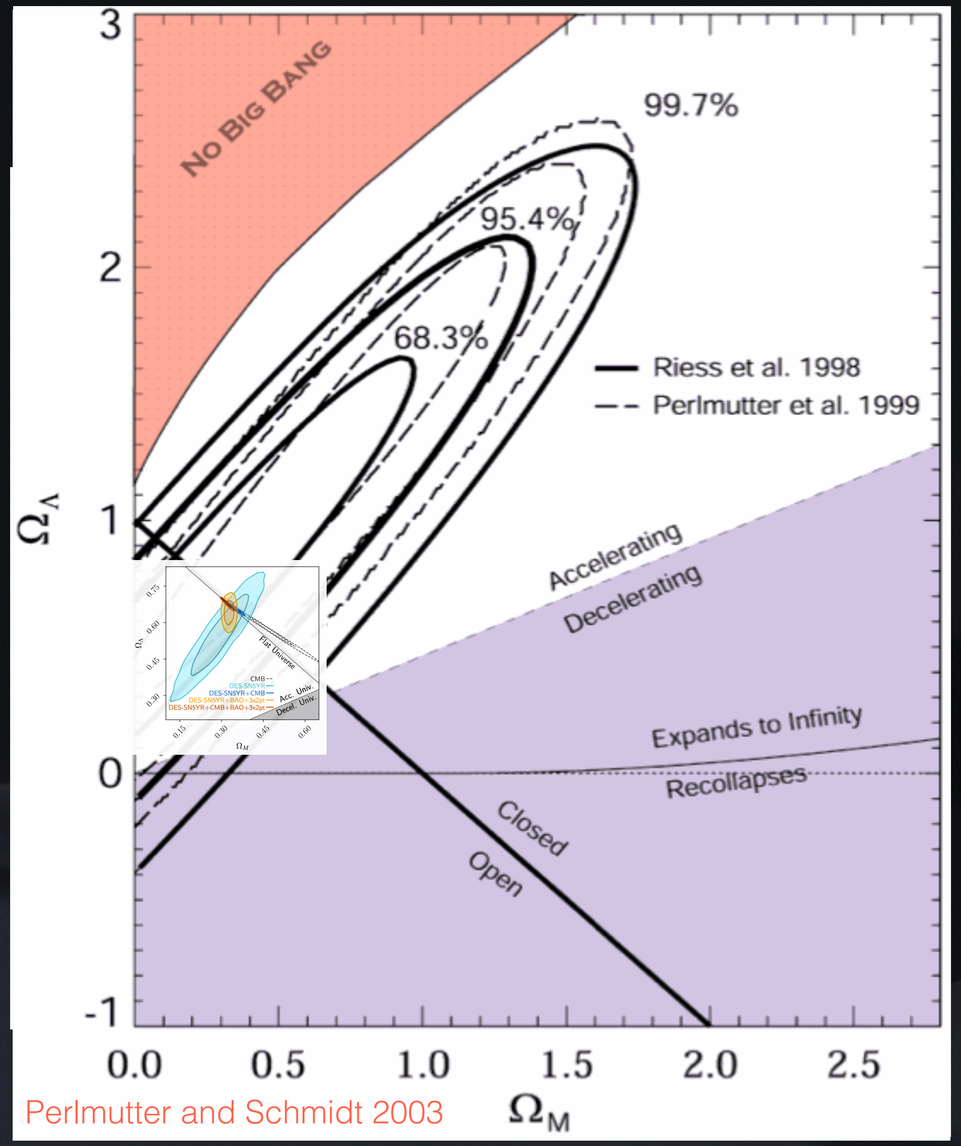
How far have we come?



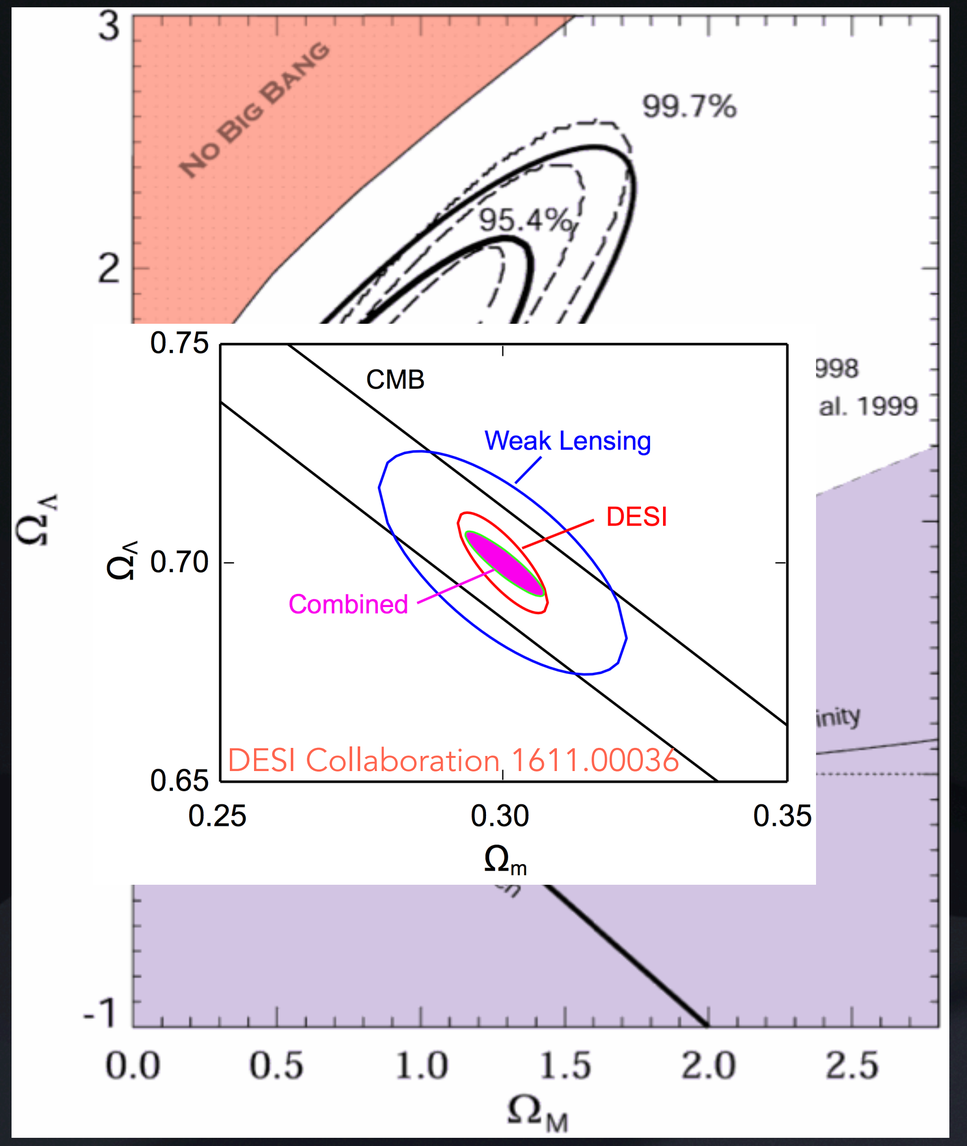
Perlmutter and Schmidt 2003



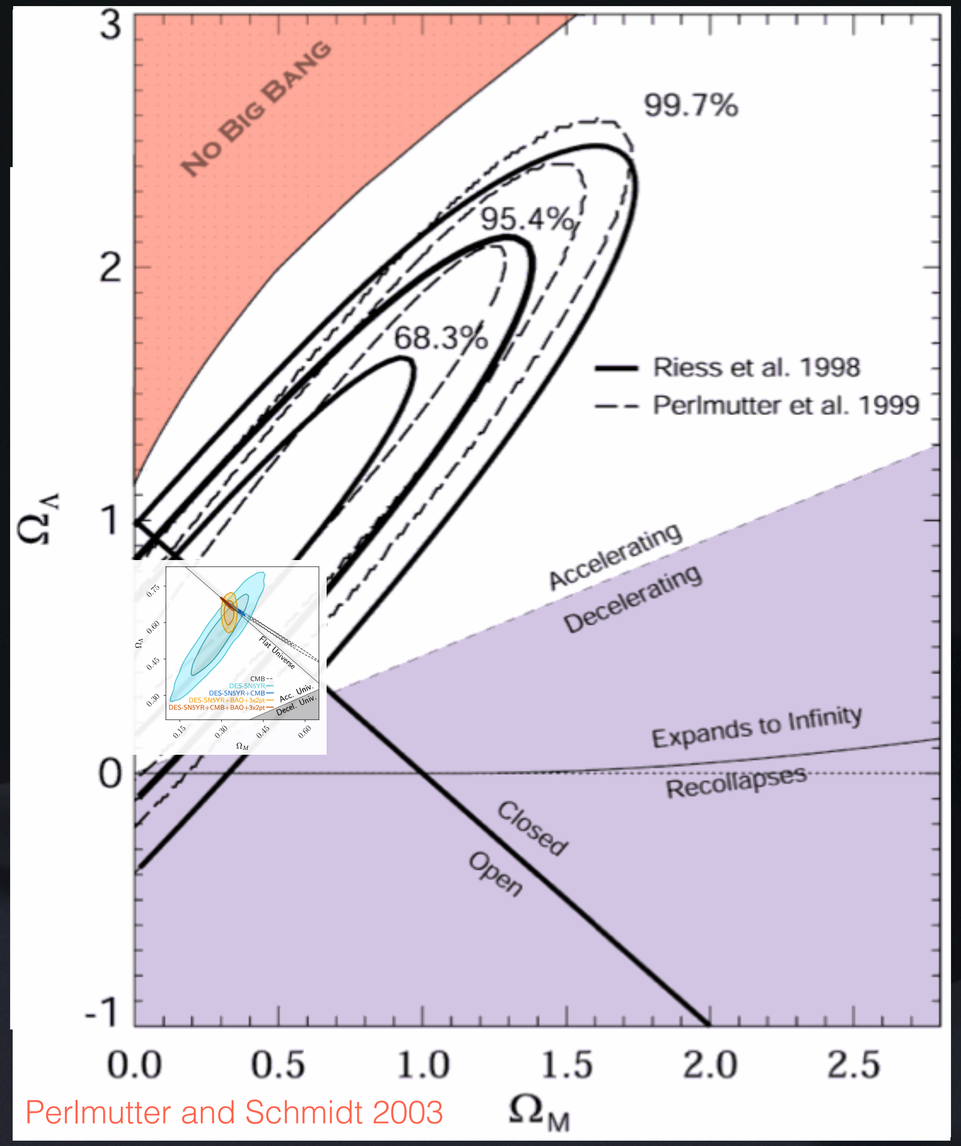
How far will we go?



Perlmutter and Schmidt 2003



How far will we go?



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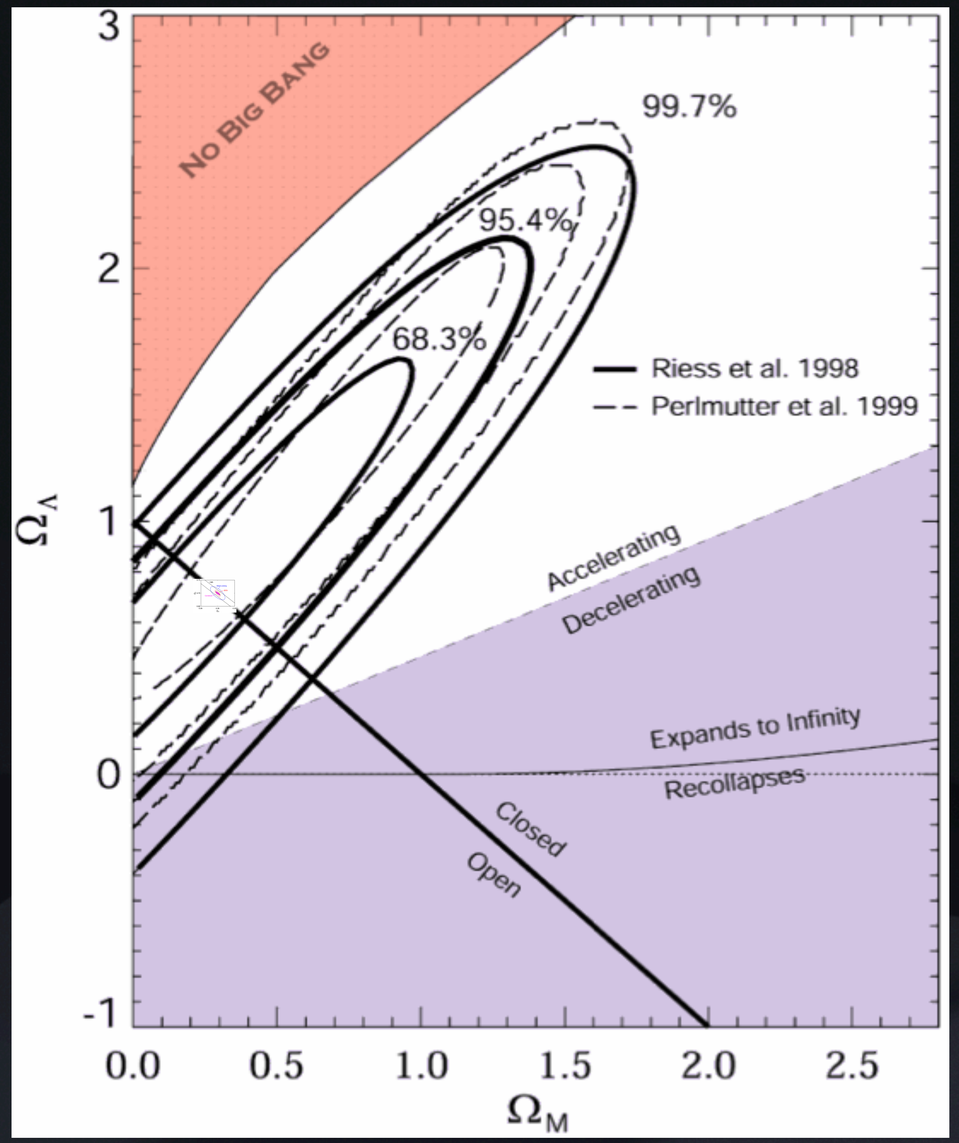
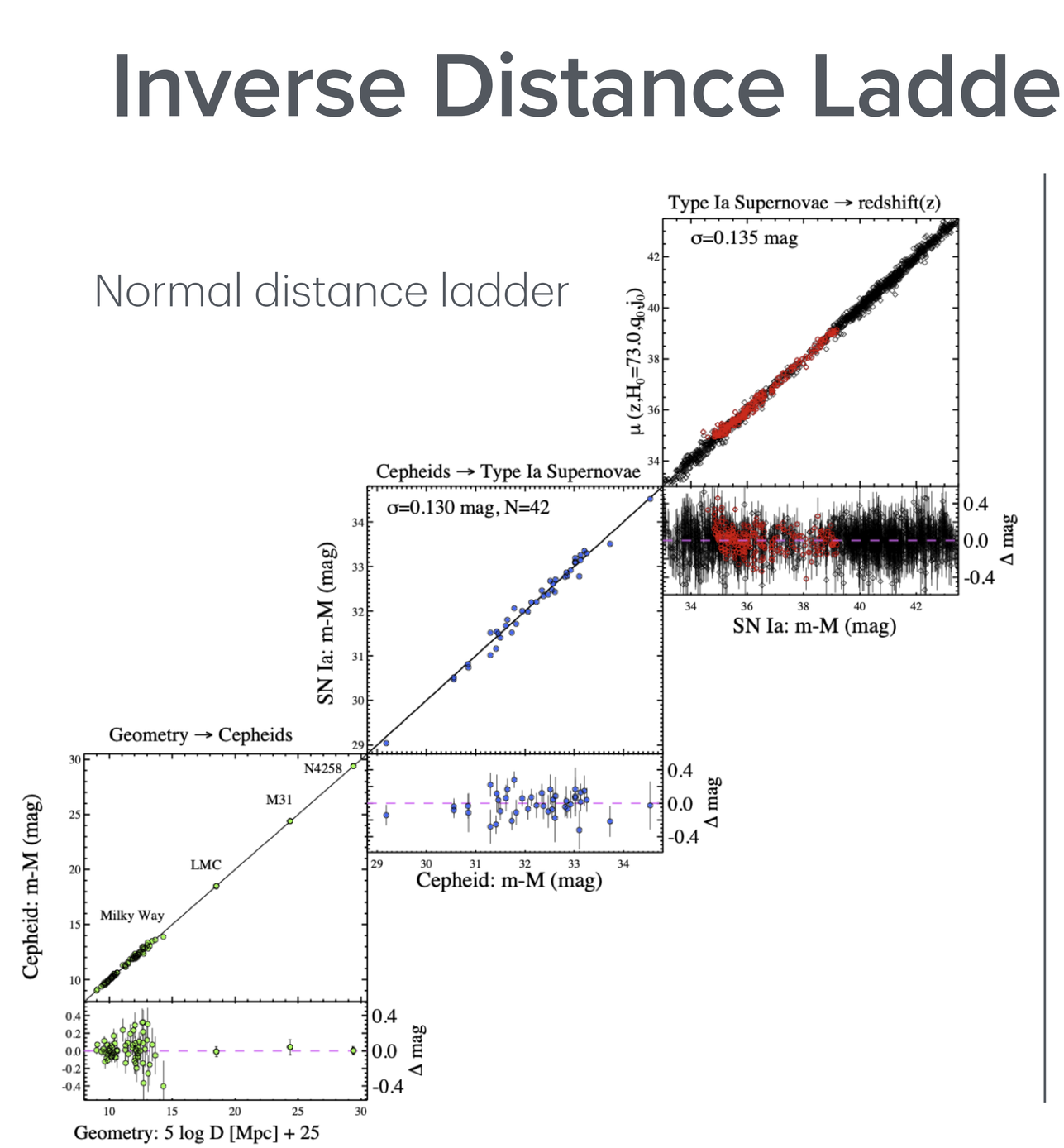


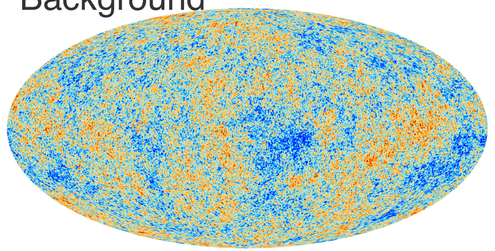
Inverse Distance Ladder

Camilleri et al. arXiv:2406.05049



Inverse distance ladder

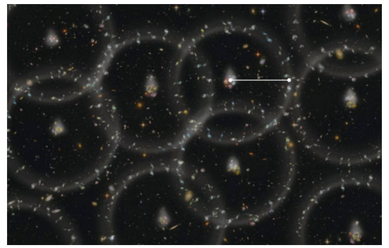
Start at the Cosmic Microwave Background



$z > 1000$

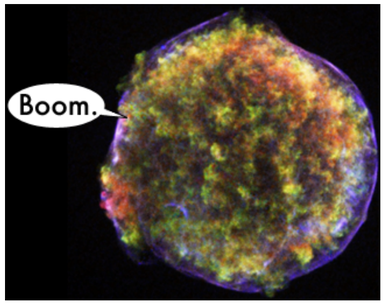
r_d

Sound horizon scale sets the scale of the Baryon Acoustic Oscillations (BAO)

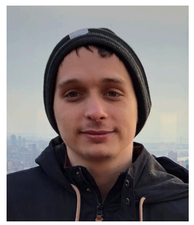


$2.330 > z > 0.295$

The BAO then break the H_0 - M_B degeneracy of the SN



$1.15 > z > 0.025$

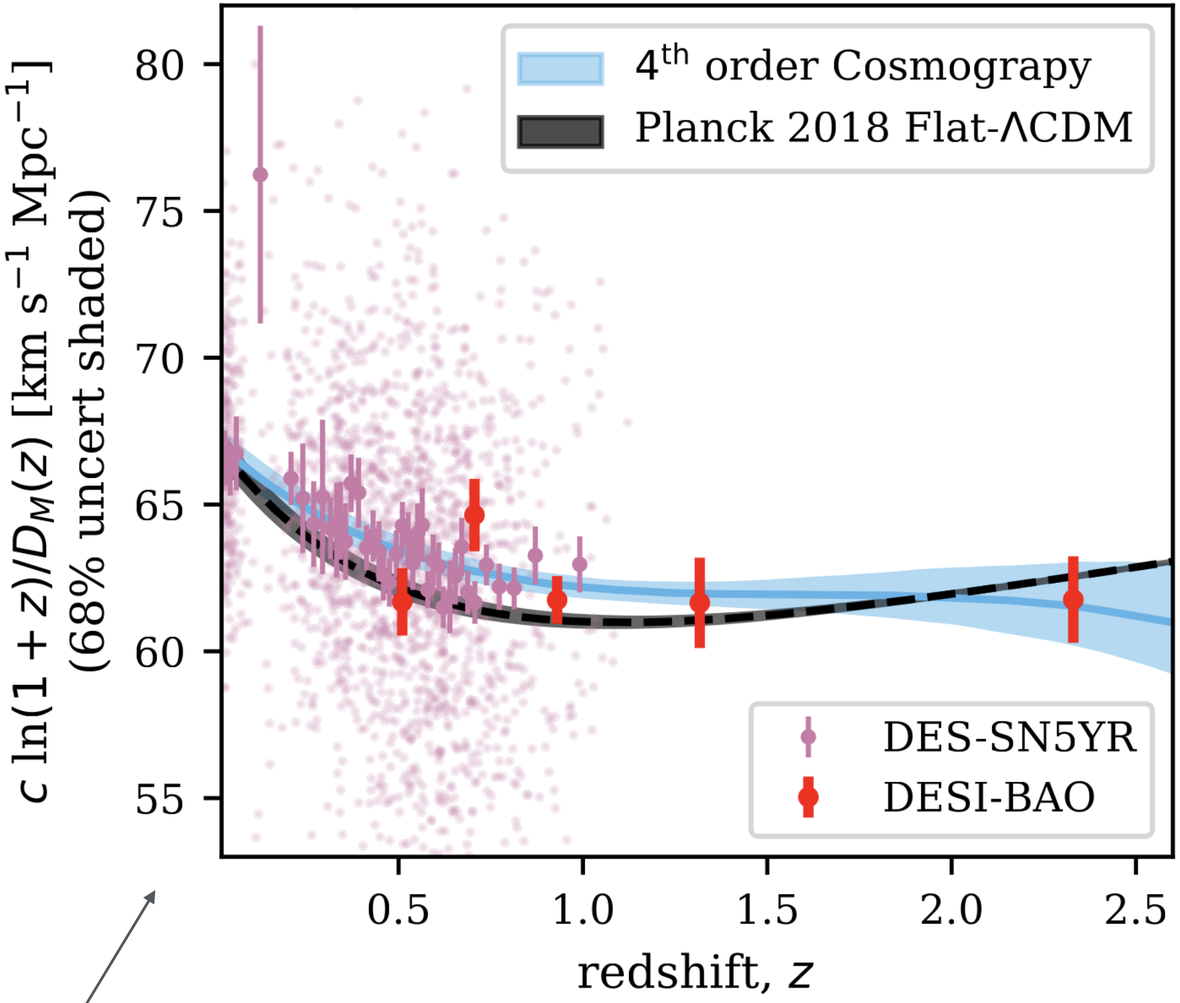


Ryan Camilleri et al. 2024

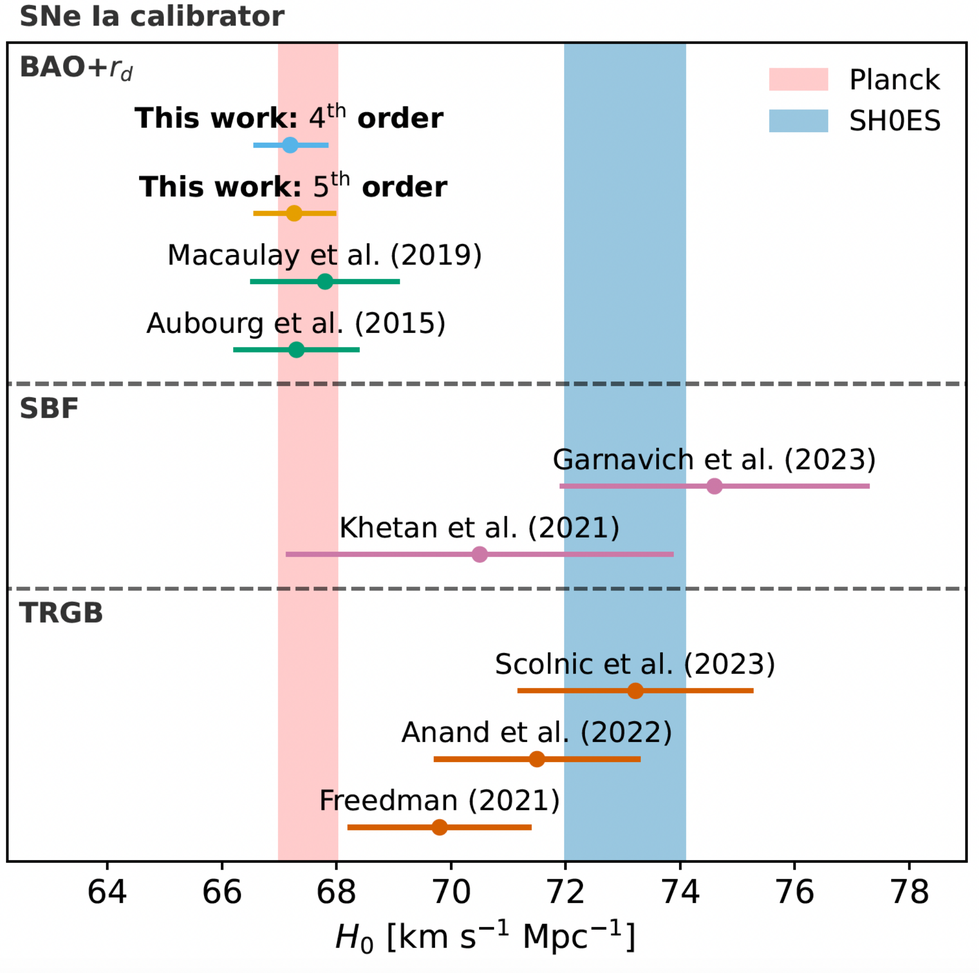
Inverse Distance Ladder

Camilleri et al. arXiv:2406.05049

$$H_0 = 67.19^{+0.66}_{-0.64}\ \mathrm{km\ s^{-1}\ Mpc^{-1}}$$

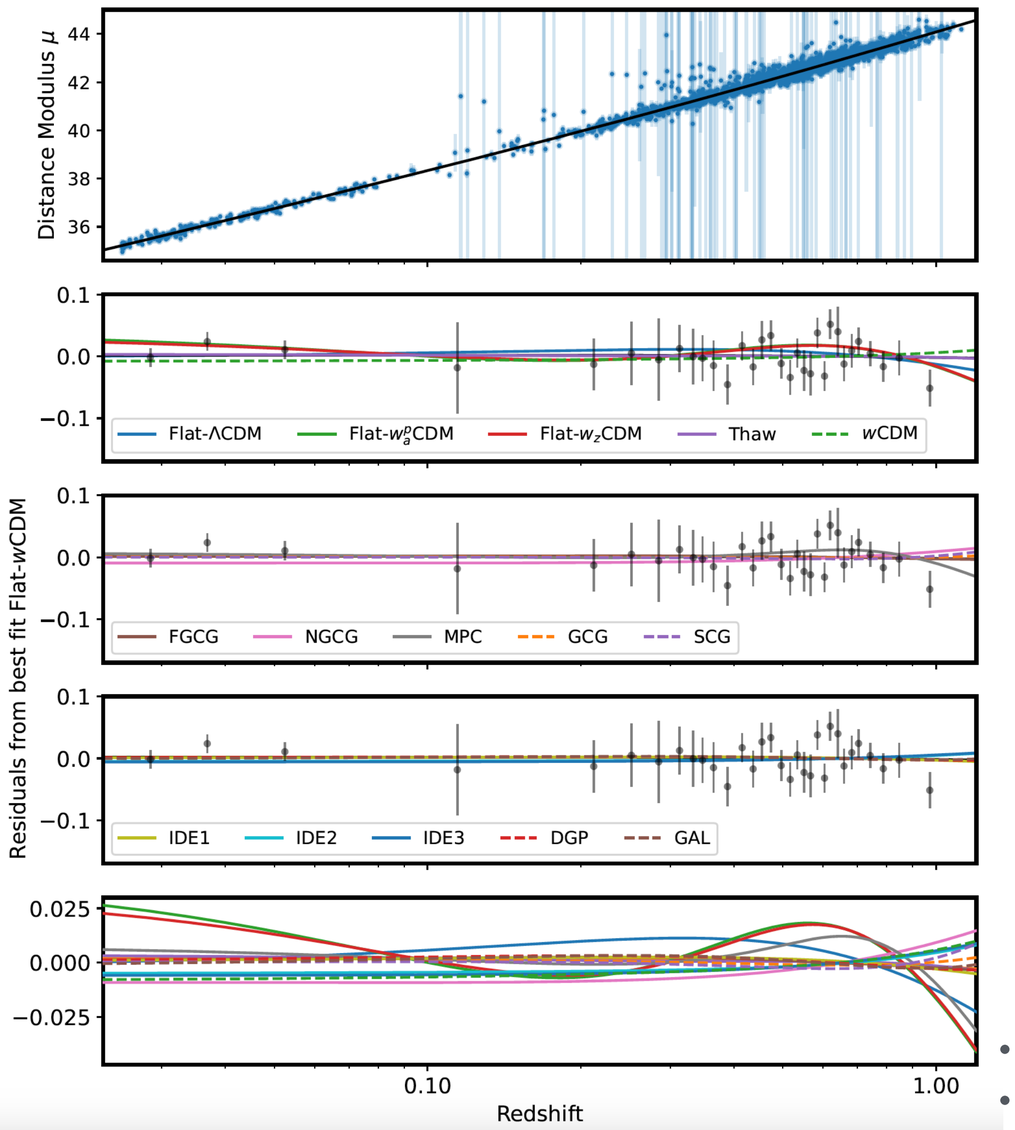


Intercept shows H_0



Exotic Cosmological Models

Camilleri et al. arXiv:2406.05048



Model	DES-SN5YR $\frac{1}{2}\Delta$AIC	DES-SN5YR $\Delta\ln S$	DES-SN5YR χ^2/dof	Model	DES-SN5YR + CMB-R + BAO-θ_* $\frac{1}{2}\Delta$AIC	DES-SN5YR + CMB-R + BAO-θ_* $\Delta\ln S$	DES-SN5YR + CMB-R + BAO-θ_* χ^2/dof
Cosmography - Third Order	−0.9	−1.37	1641 / 1733 = 0.947				
Cosmography - Fourth Order	−3.6	−4.39	1633 / 1732 = 0.943				
Flat-ΛCDM					0.0		1665 / 1749 = 0.952
ΛCDM					−0.10		1664 / 1747 = 0.952
wCDM					−3.64		1655 / 1747 = 0.947
Flat-w_0w_zCDM					−4.16		1655 / 1747 = 0.947
Flat-w_a^pCDM					−4.17		1655 / 1747 = 0.947
Thaw					−4.60		1655 / 1747 = 0.947
SCG					138.03		1940 / 1748 = 1.110
FGCG					−3.94		1657 / 1748 = 0.948
GCG					−3.71		1656 / 1747 = 0.948
NGCG					−4.08		1655 / 1747 = 0.947
MPC					−3.94		1655 / 1747 = 0.947
IDE1					−3.70		1656 / 1747 = 0.948
IDE2					−3.75		1656 / 1747 = 0.948
IDE3					−3.82		1655 / 1747 = 0.947
DGP					31.11		1726 / 1748 = 0.988
GAL					72.10		1808 / 1748 = 1.035
	DES-SN5YR$_{\rm cut}$				DES-SN5YR$_{\rm cut}$ + BAO-$\theta_{*\perp}$		
Flat-ΛCDM	0.0	0.0	1616 / 1665 = 0.970	Flat-ΛCDM	0.0	0.0	1624 / 1672 = 0.972
Timescape	−1.7	−1.72	1612 / 1665 = 0.968	Timescape	6.3	6.17	1637 / 1672 = 0.979

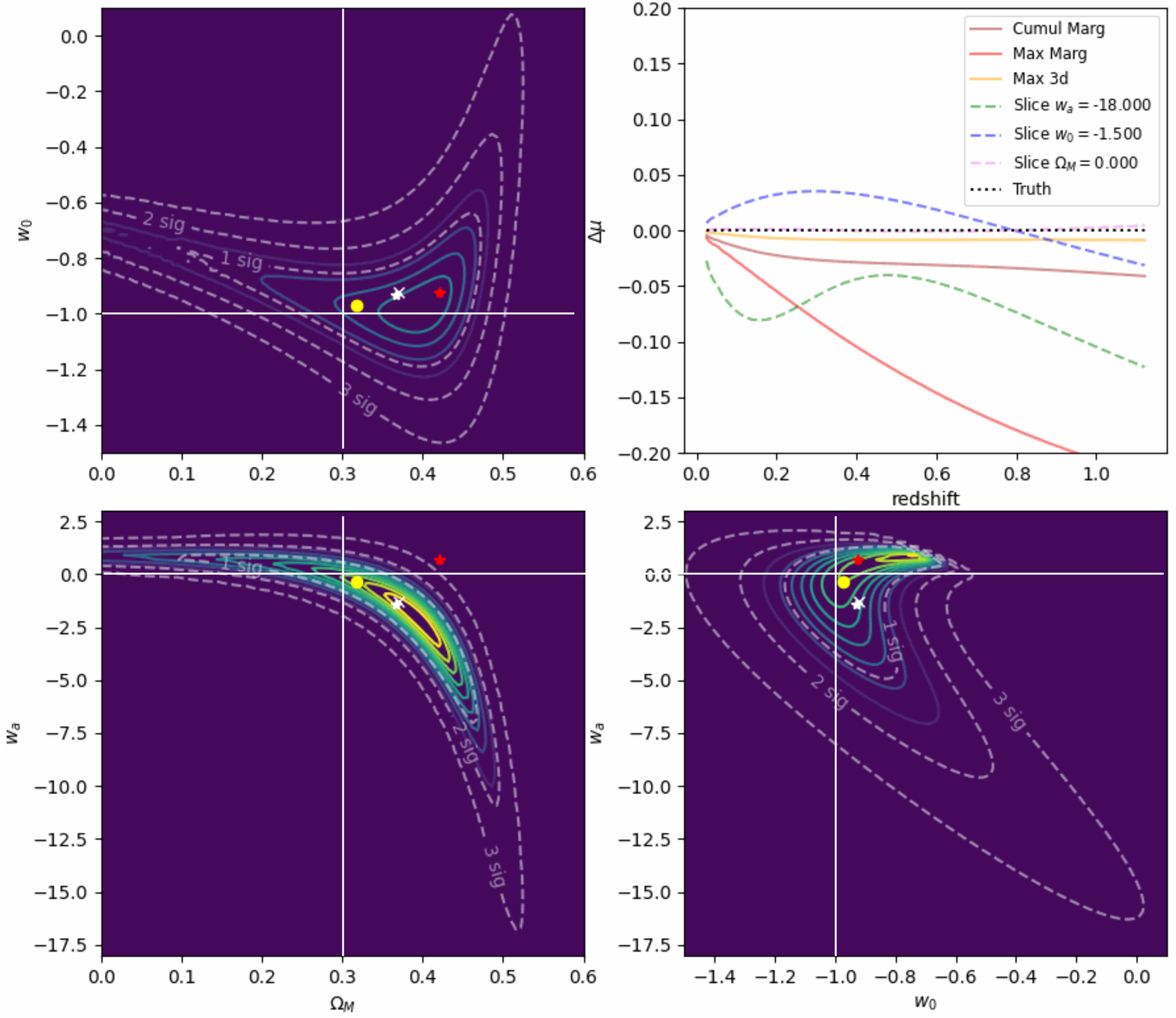
Flat generalised Chaplygin gas

Flat thawing scalar field

Flat time-varying dark energy

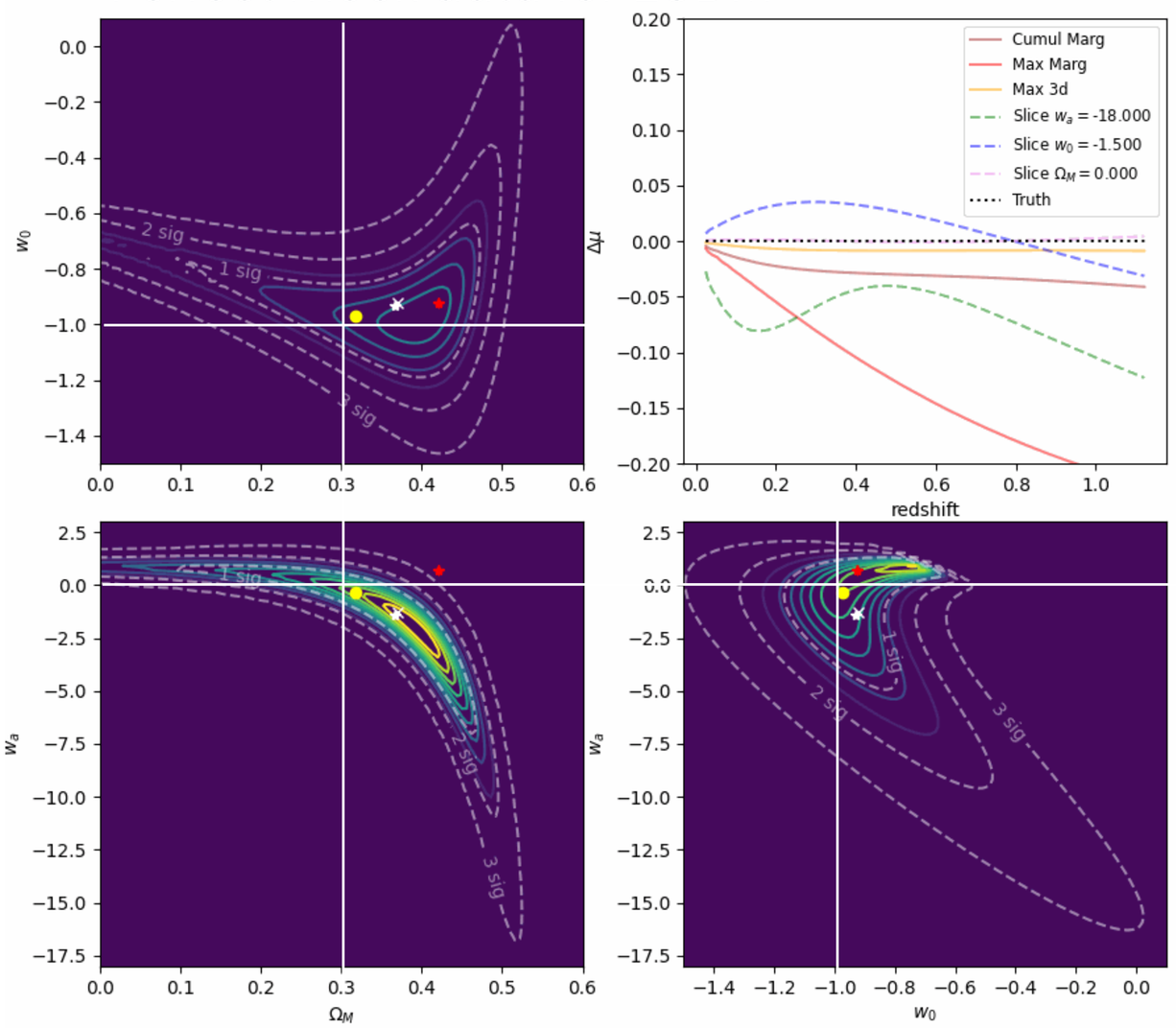
- No *strong* evidence for or against Flat-ΛCDM
- DES-SN alone: 3 models moderately preferred over Flat-ΛCDM
- DES-SN + CMB + BAO: 11 (of 15) models moderately preferred over Flat-ΛCDM

Projection effects

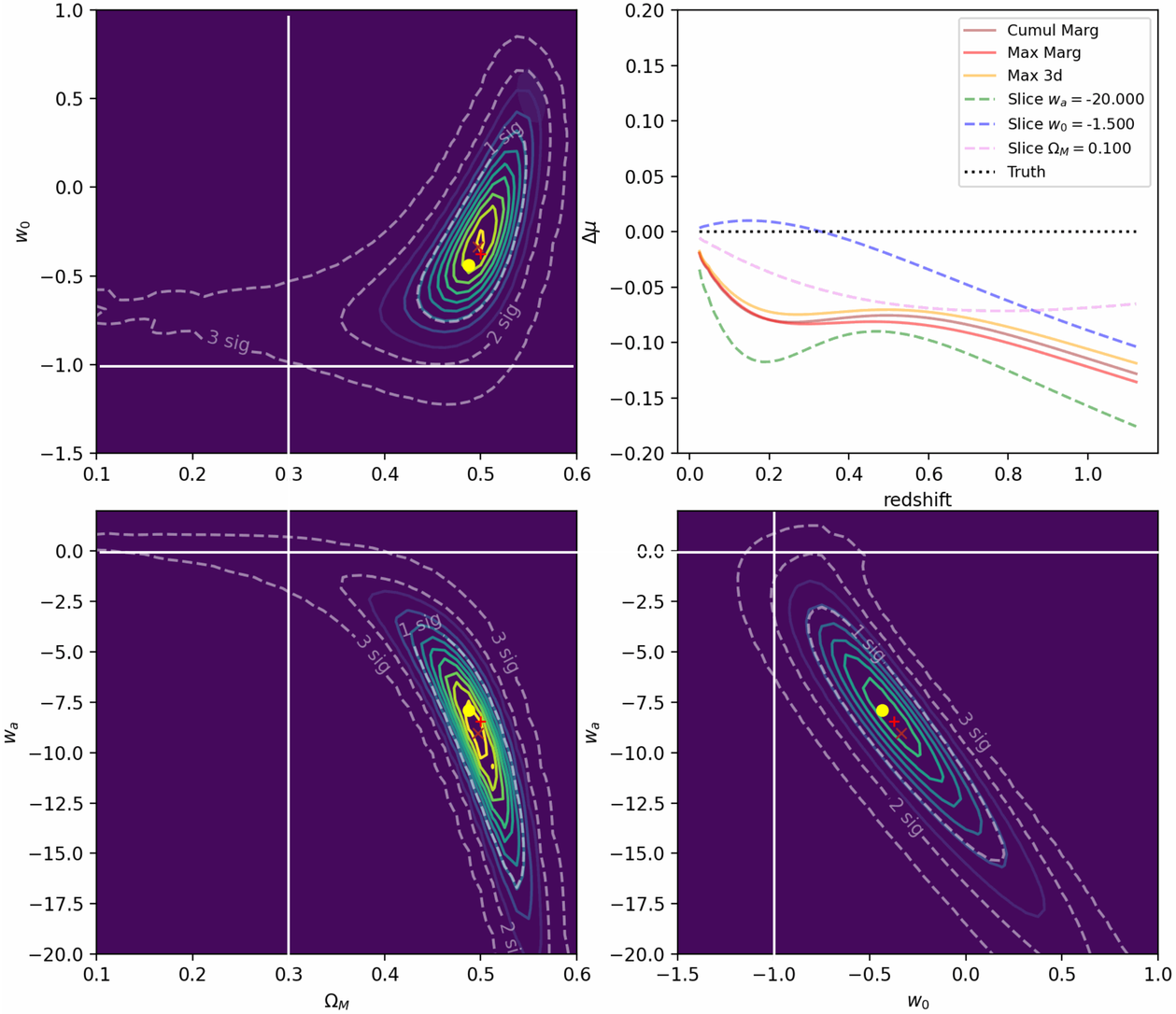


Projection effects

Perfect mock data for LCDM



Real data



Gravitational Wave Detectors

Beyond LVK

- *Gravitational waves replace SNe as "gold standard" standard candles*

4-metre Multi-Object Spectroscopic Telescope (4MOST)

Photo Credit: : VISTA, ESO

- *Next gen surveys map the entire ops Univ.*
- *(And GWs look on the hidden side of the Milky Way)*

- *DESI gives definitive measurement of expansion history*

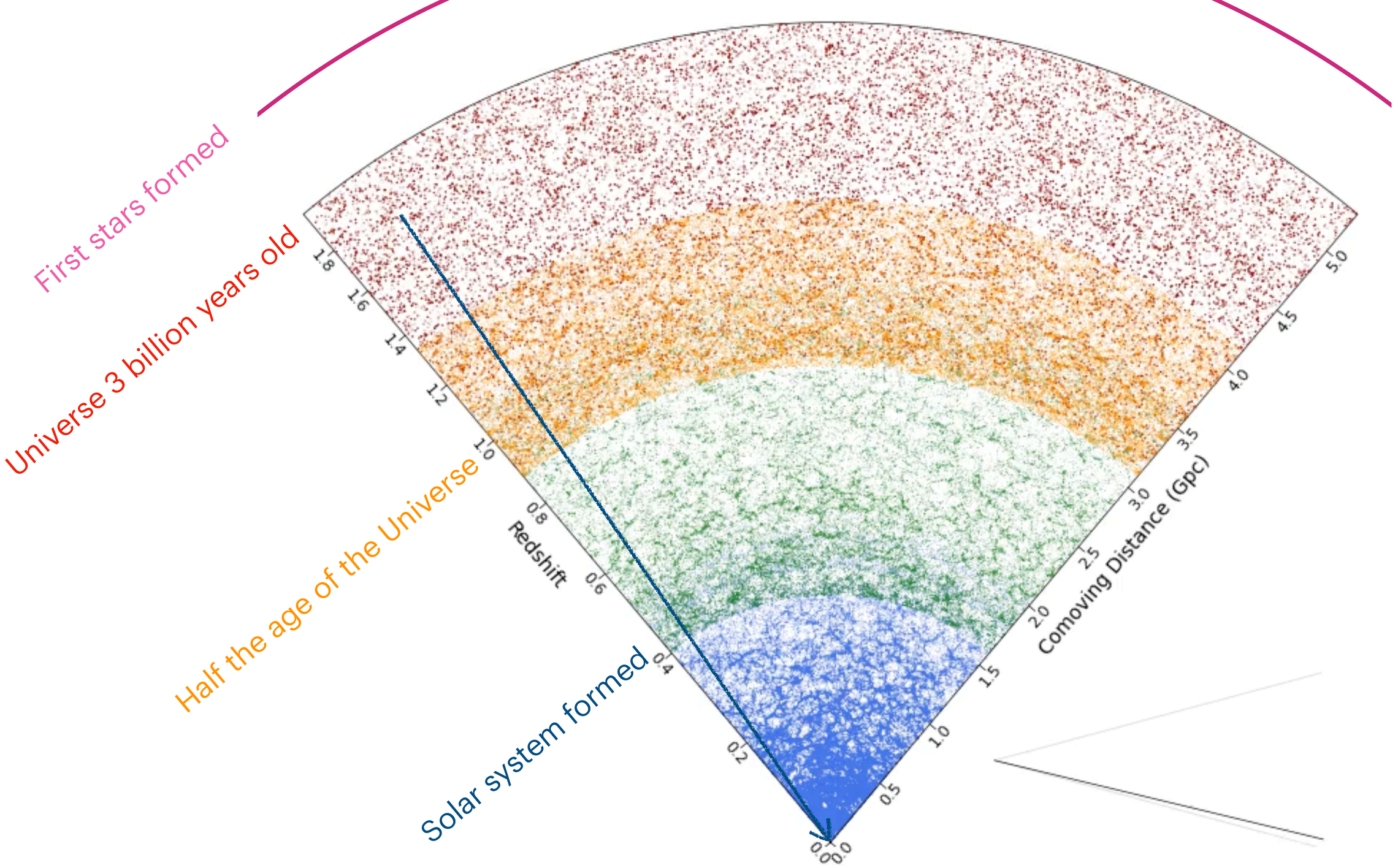
The Dark Energy Spectroscopic Instrument (DESI)

Photo Credit: Marilyn Chung, Berkeley Lab

- *Rubin LSST makes movie of the sky*

Vera C. Rubin Observatory

Photo Credit: Me


First stars formed
Universe 3 billion years old
Half the age of the Universe
Solar system formed
Redshift
Comoving Distance (Gpc)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

Enormous thanks to everyone involved

AAT

2dF (OzDES)

Blanco

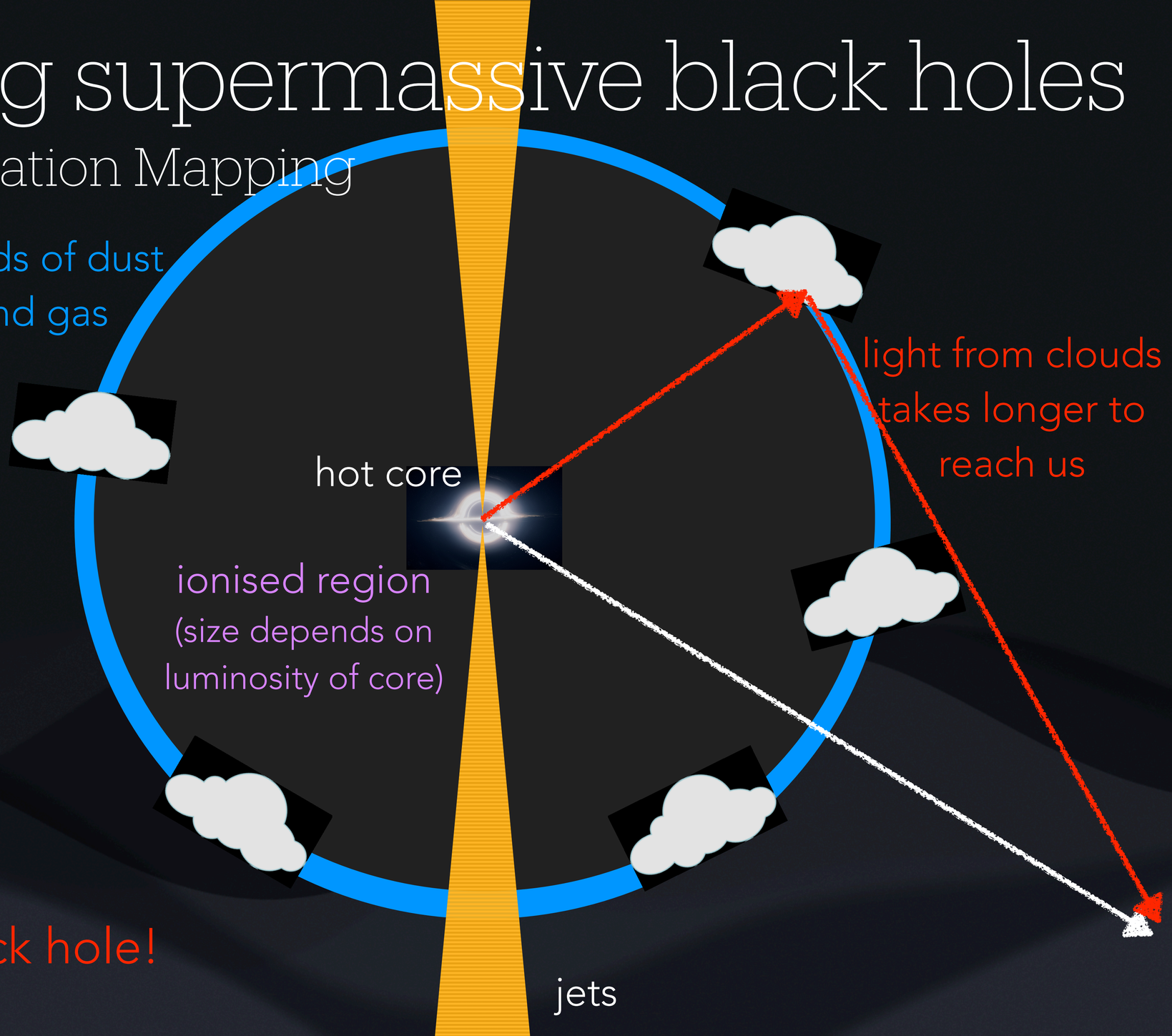
DECam (DES)

Mayall

DESI

Weighing supermassive black holes

AGN Reverberation Mapping

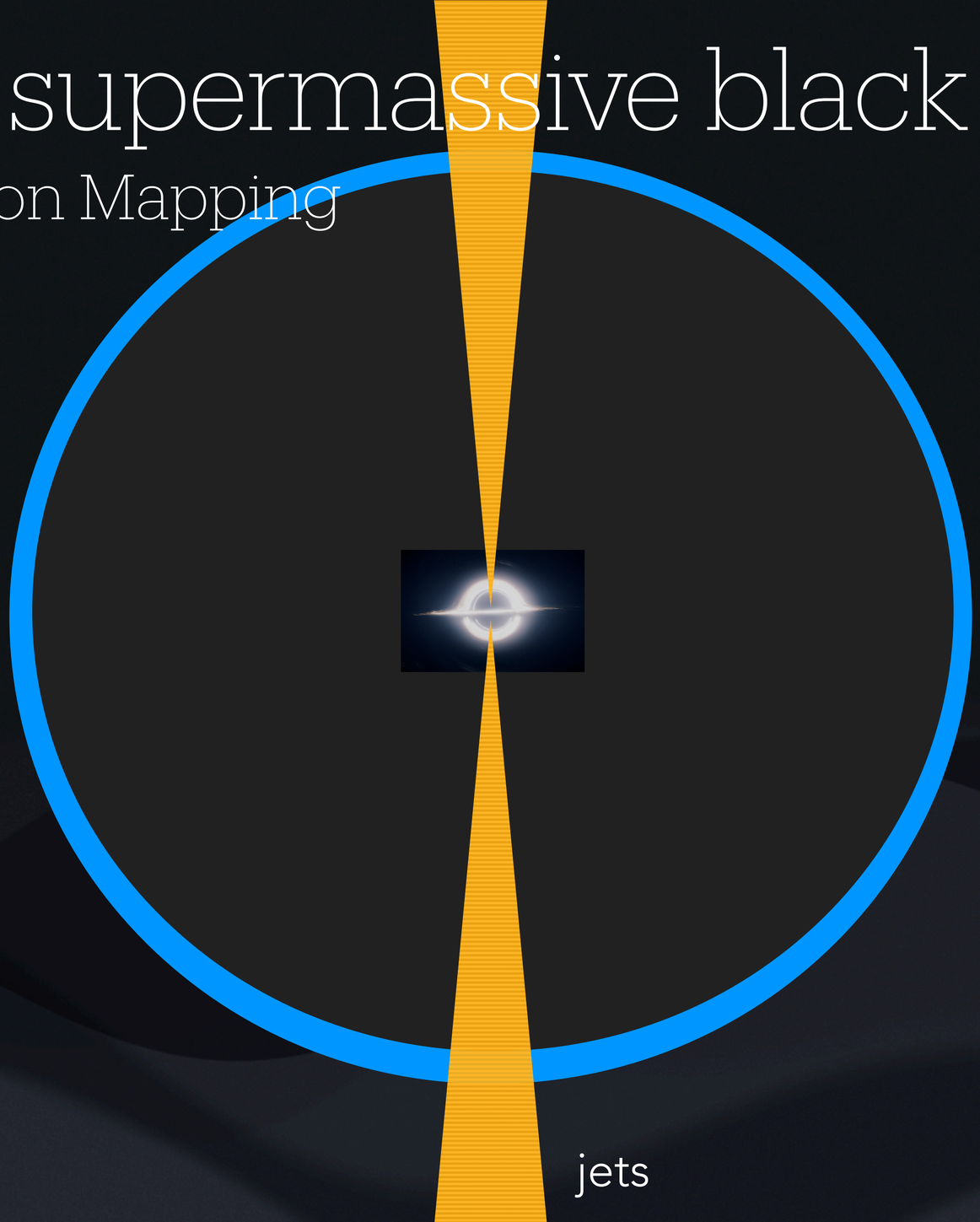


time delay → size

→ mass of black hole!

Weighing supermassive black holes

AGN Reverberation Mapping



Cygnus A

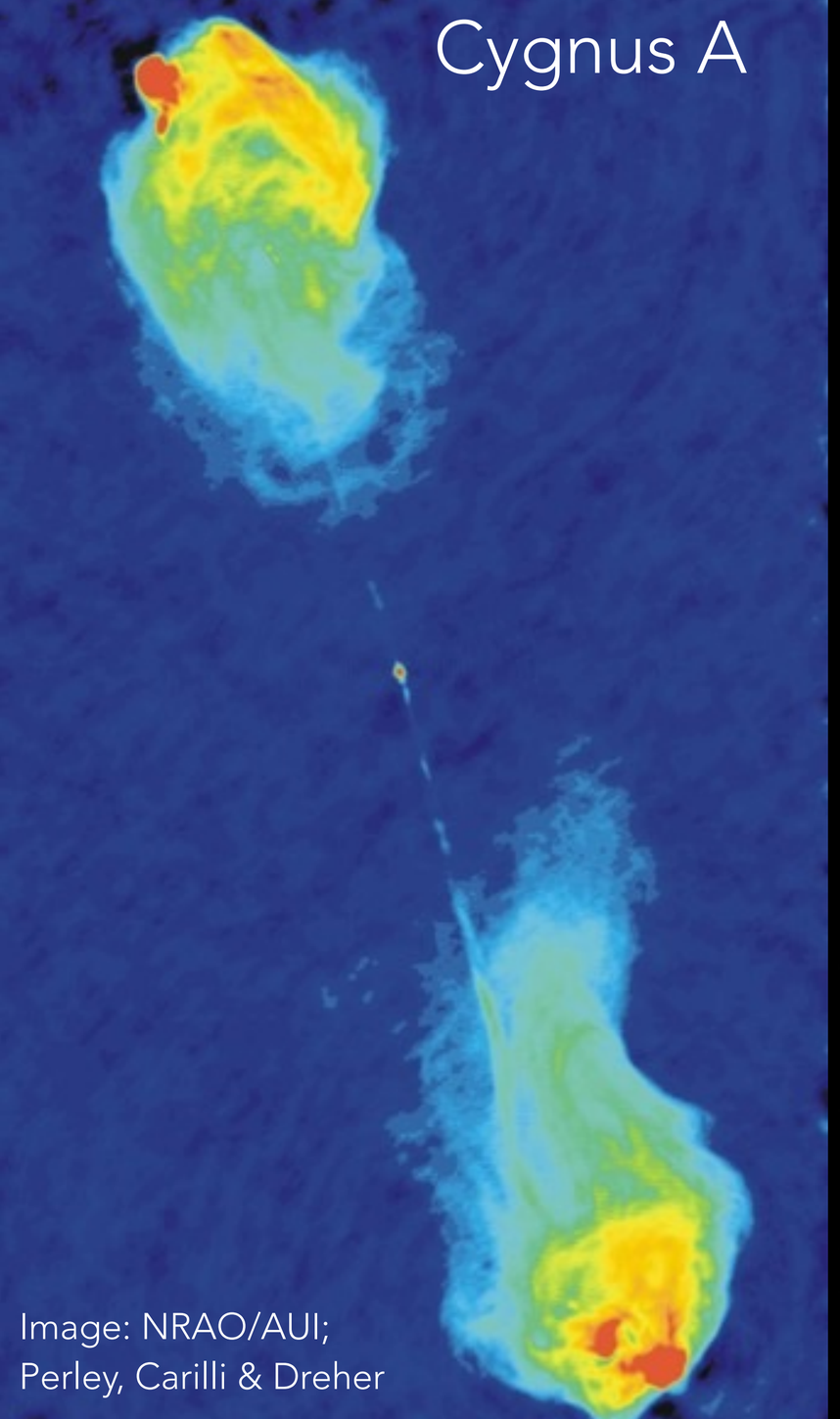


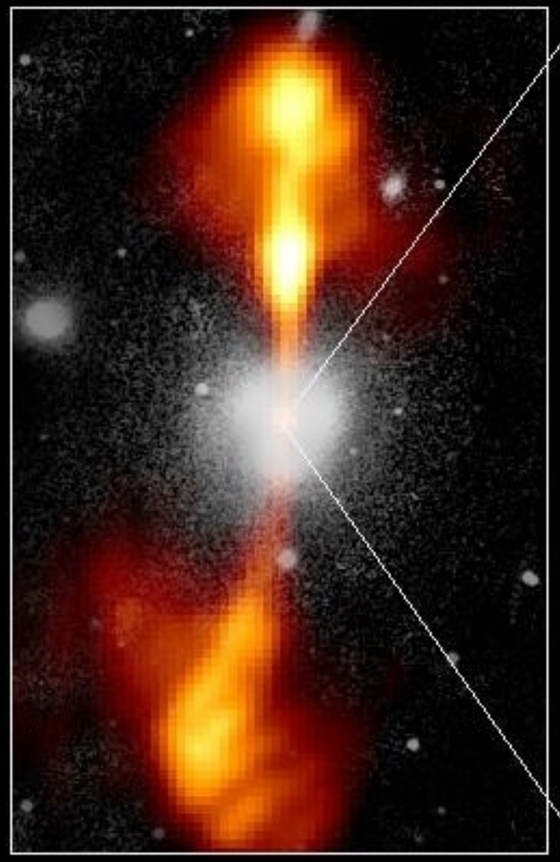
Image: NRAO/AUI;
Perley, Carilli & Dreher

Core of Galaxy NGC 4261

Hubble Space Telescope

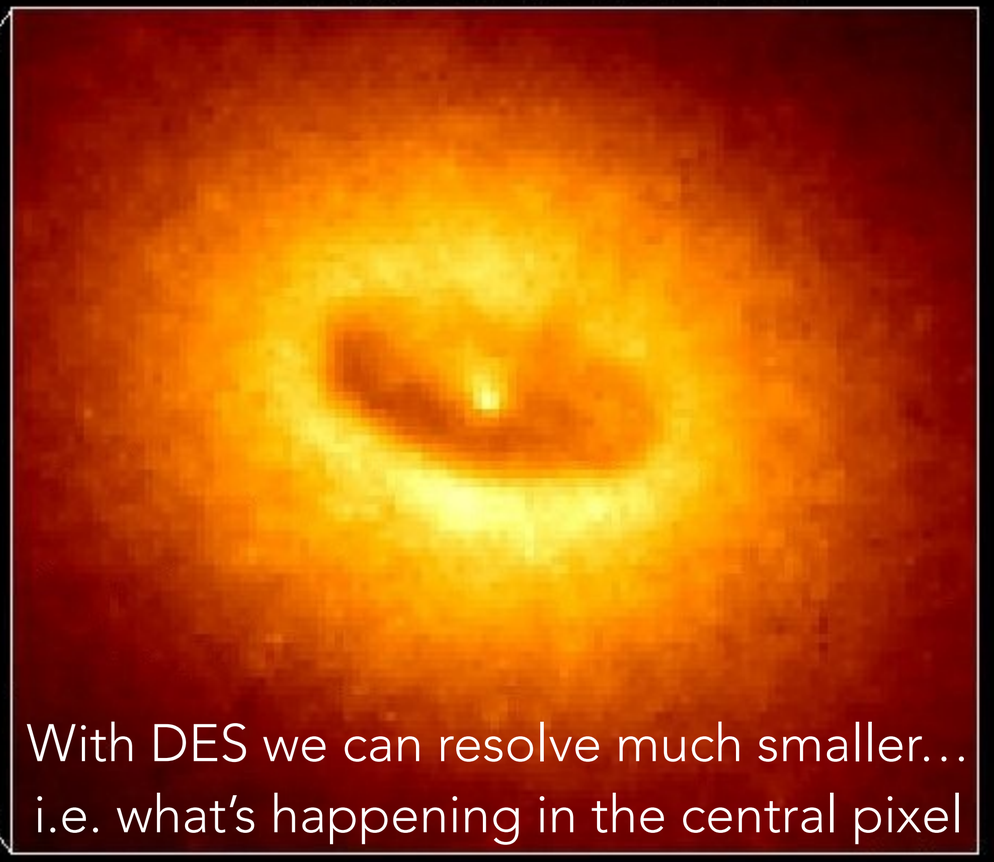
Wide Field / Planetary Camera

Ground-Based Optical/Radio Image



380 Arc Seconds
88,000 LIGHT-YEARS

HST Image of a Gas and Dust Disk



With DES we can resolve much smaller…
i.e. what's happening in the central pixel

17 Arc Seconds
400 LIGHT-YEARS

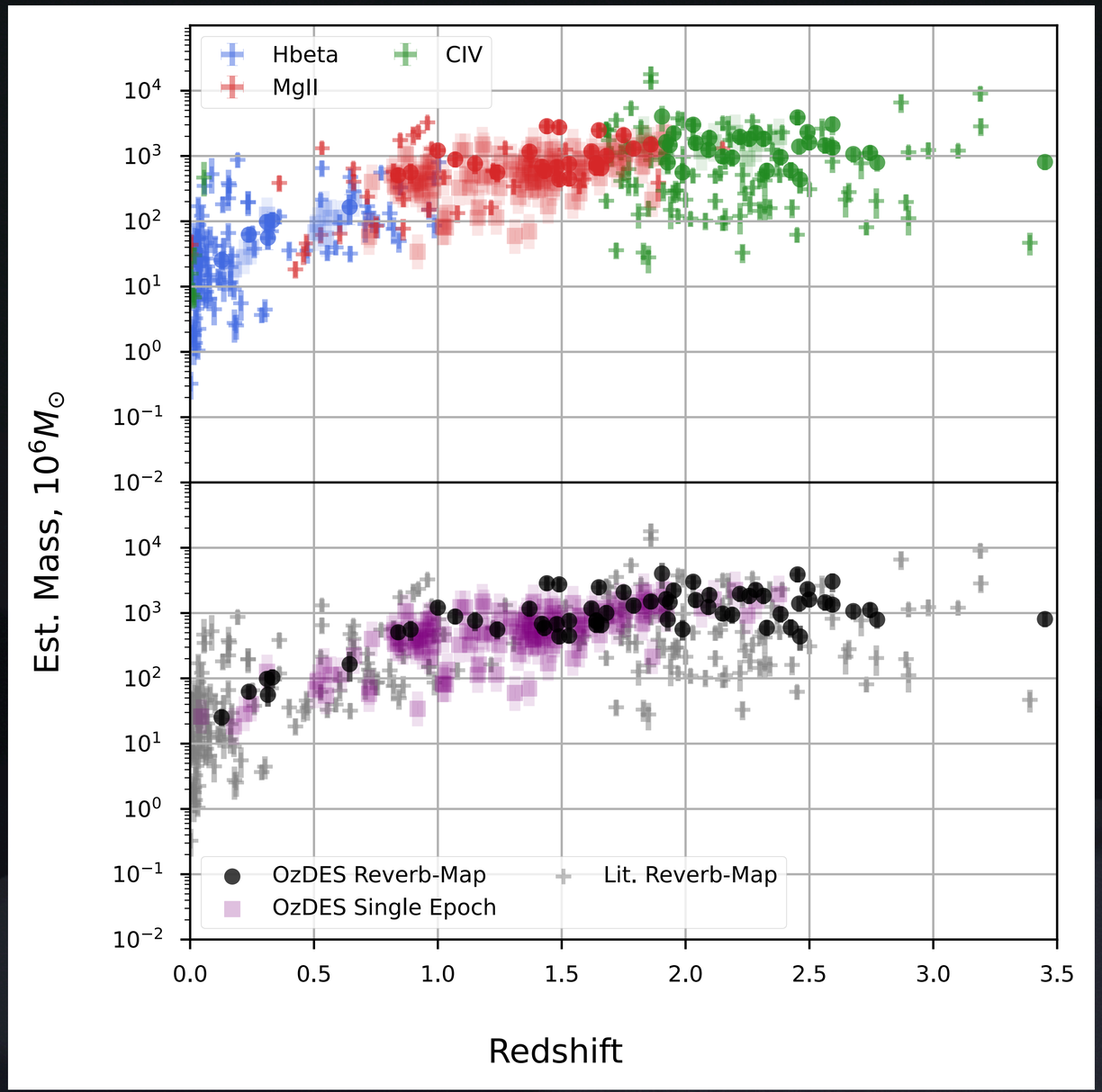
Weighing supermassive black holes

AGN Reverberation Mapping

62 new reverberation mapped black holes

- 8 Hβ
- 25 Mg II
- 29 C IV

Plus 160 single epoch masses.



The Future

Gravitational waves “rule”

Dark Energy Survey SN Cosmology Final Results

Summary

- DES-SN5YR is the largest and deepest single-telescope SN sample to date
- Excellent control of selection effects and contamination
- Found hints that dark energy may vary.

Future

- Analyse DES-SN5YR using the Bayesian Hierarchical Method UNITY
- Updating the Low-z sample (ZTF, DEBASS)
- DES+SDSS+PanSTARRS: a Hubble diagram of 3550 SNe Ia
- fully independent from Pantheon+ and Union3.
- Working on the next generation of SN samples...

DES Collaboration 2024

Key paper 2401.0292

Vincenzi et al. 2401.02945

Bonus science

Shah et al. 2406.05047

Camilleri et al. 2406.05048

Camilleri et al. 2406.05049

White et al. 2406.05050

Popovic et al. 2406.05051