

# Dark Energy Task Force: Methods and Results

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23 May 2006



## Outline:

- 1) Data Models: General Discussion
- 2) Data Models: An illustration (SNLS)
- 3) A technical point: The role of correlations
- 4) DETF quantitative results.
- 5) DETF legacy
- 6) (FAQ)
- 7) (Looking to the future)

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The plan:

- ➔ i) Model a possible data set
- ii) Base models on Whitepapers and knowledge within the DETF.
- iii) Introduce “nuisance parameters” to model systematics
- iv) Construct “optimistic” pessimistic cases for each possible experiment to illustrate the various uncertainties (typically to do with systematics)
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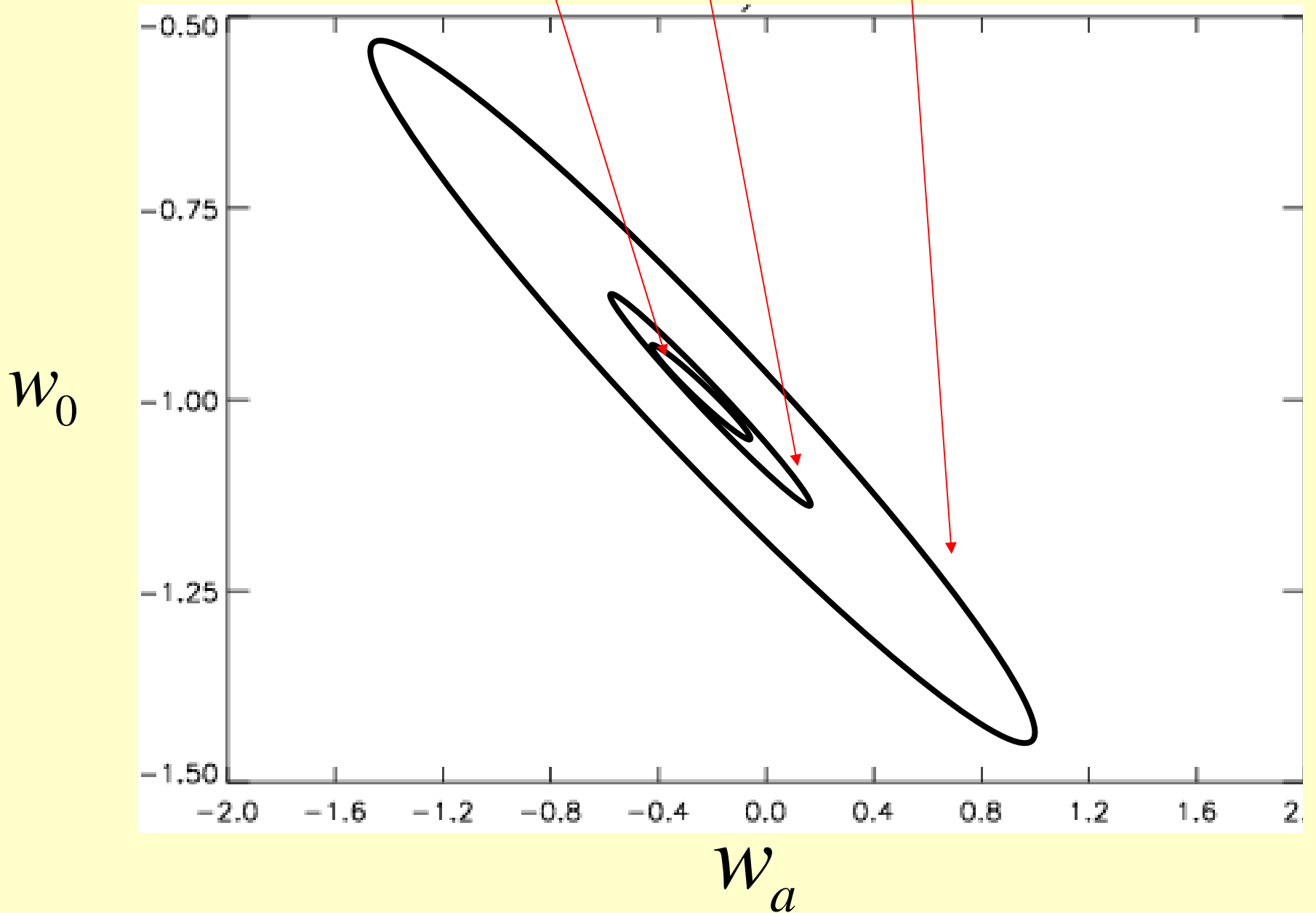
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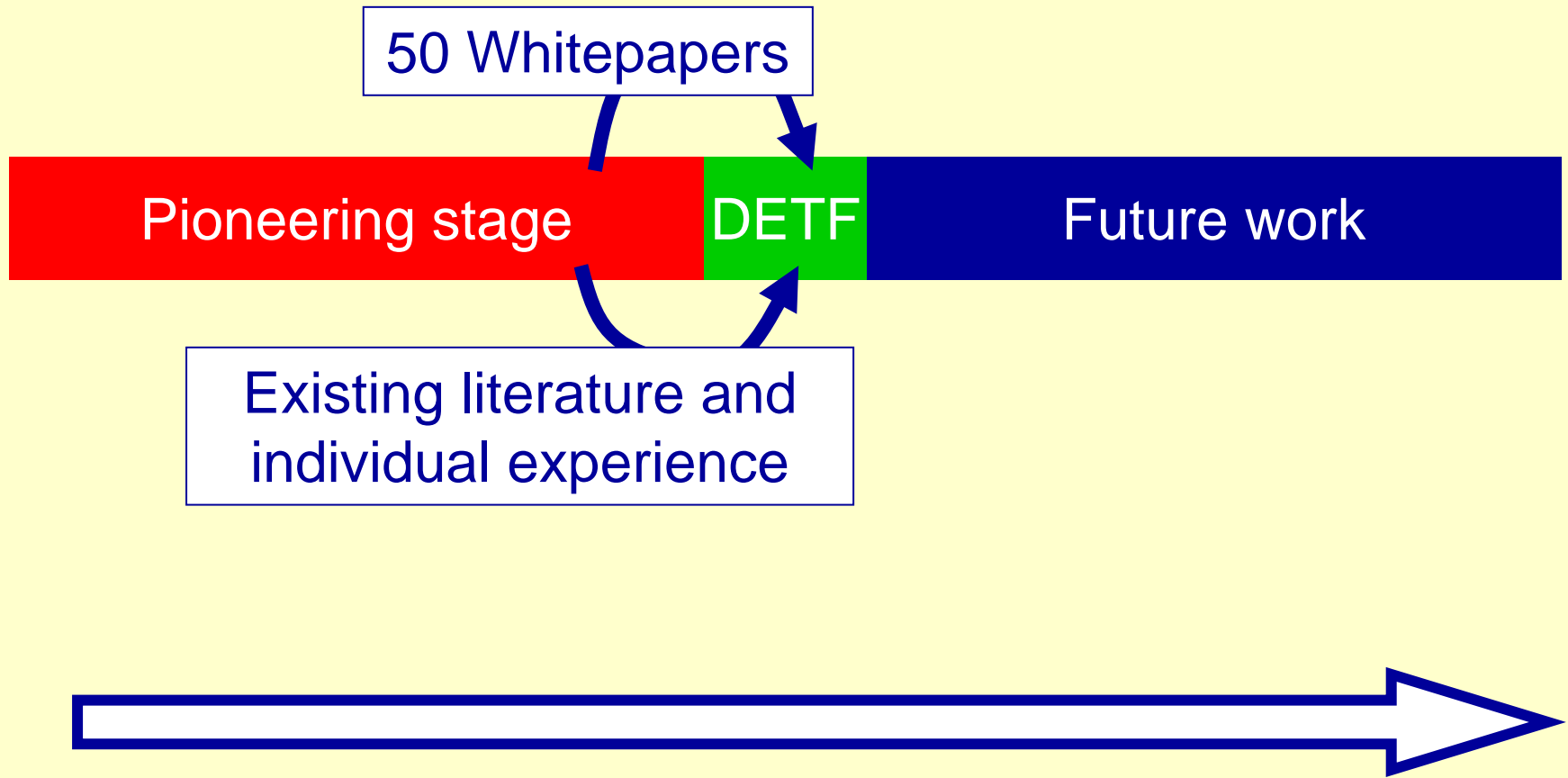
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# Systematics: none, optimistic, pessimistic



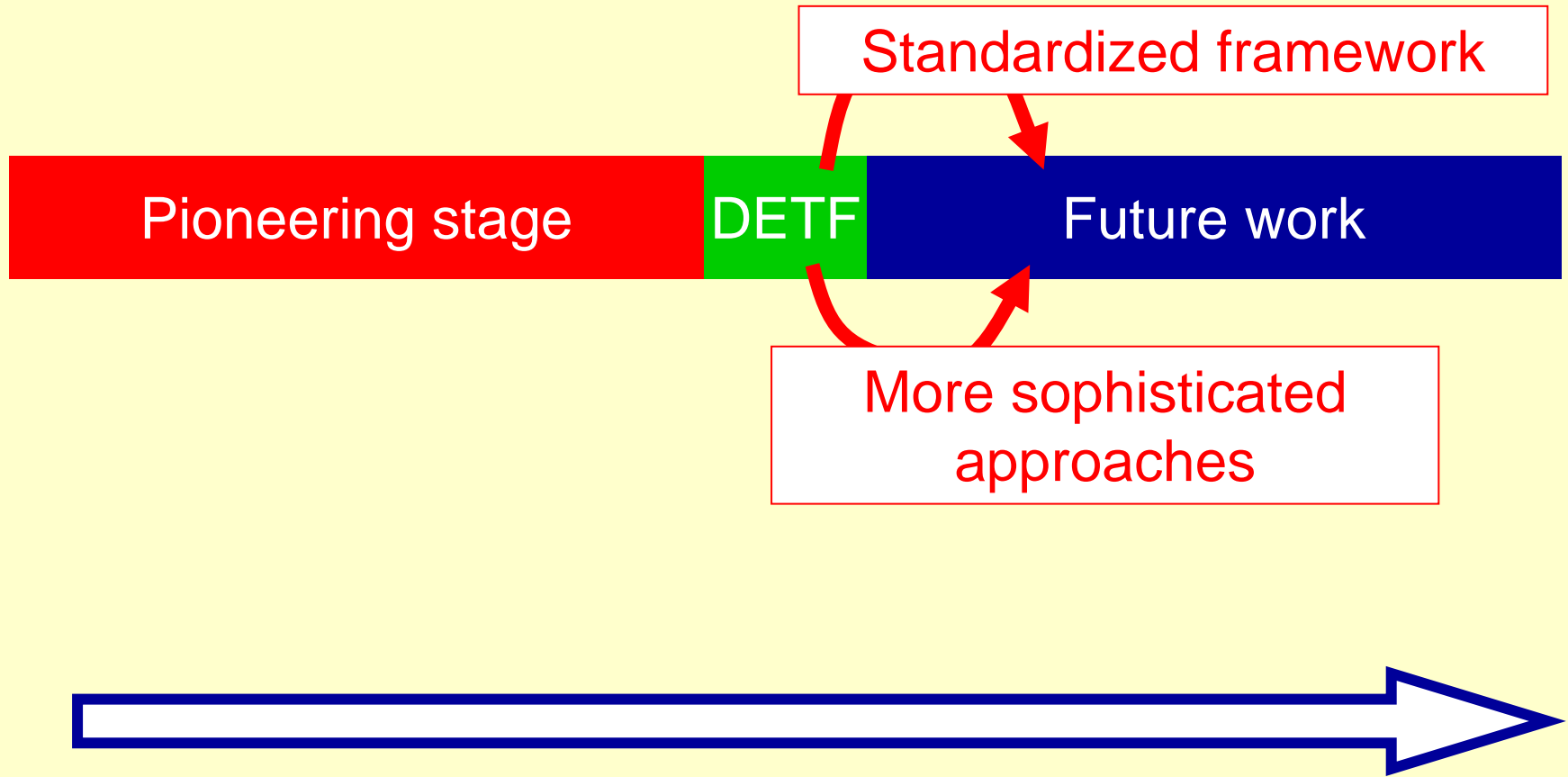
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Our position in the dark energy timeline



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## 2) Data Models: An illustration (SNLS)

zmax	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0.08
zmin	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0.03	0.03
z_i	0.95	0.85	0.75	0.65	0.55	0.45	0.35	0.25	0.15	0.065	0.055
N_bin	68	104	111	104	100	86	68	43	11	4	500
sigma_bin	0.3	0.3	0.09	0.07	0.06	0.04	0.02	0.02	0.02	0.02	0.02

Freedman &  
Suntzeff

$$X_i = \mu(z_i) = 5 \log_{10}(d_L(z_i)) + 25$$

$$\sigma_i = \sqrt{\frac{\sigma_{bin}^2 + (0.15)^2}{N_{bin}}}$$

$$\chi^2 = \Delta \vec{X} C^{-1} \Delta \vec{X}$$

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sigma_bin	0.3	0.3	0.09	0.07	0.06	0.04	0.02	0.02	0.02	0.02	0.02

$$C^{-1} = \text{diag} \left\{ \frac{1}{\sigma_1}, \frac{1}{\sigma_2}, \dots, \frac{1}{\sigma_N} \right\} =$$

$$\begin{pmatrix} \frac{1}{\sigma_1^2} & 0 & 0 & 0 & & & 0 \\ 0 & \frac{1}{\sigma_2^2} & & & & & \\ & & \dots & 0 & & & \\ 0 & 0 & 0 & \frac{1}{\sigma_i^2} & 0 & 0 & 0 \\ & & & 0 & \dots & & \\ & & & 0 & & \dots & 0 \\ 0 & & & 0 & 0 & 0 & \frac{1}{\sigma_N} \end{pmatrix}^{15}$$

## 2) Data Models: An illustration (SNLS)

“Nuisance parameters” (can be used to parameterize aspects of the expt, including systematics).

Example (SNe):  $\mu(z) \equiv m(z) - \mathcal{M}$

Data

Includes info about M and H → poorly determined

$$\mathcal{M}(z) = \mathcal{M}_0 + \mathcal{M}_1 z + \mathcal{M}_2 z^2$$

Additional parameters in Fisher Matrix

Priors on  $\mathcal{M}_i$  express different possible systematic uncertainties

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Other features:

- Near sample of 500 SNe also assumed (“Suntzeff step”)
- Other simulated data with photo-z’s has nuisance parameters for the z’s

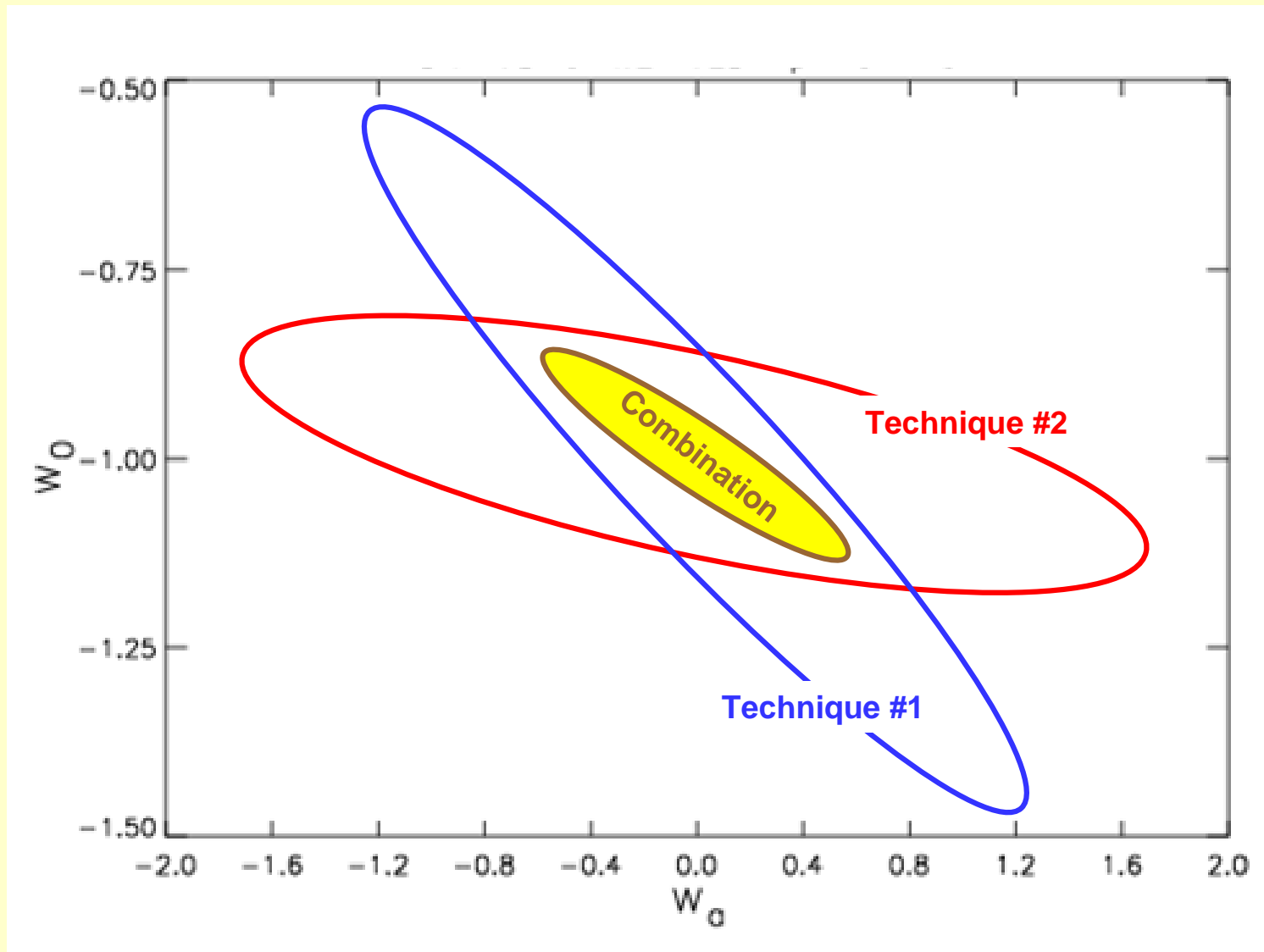
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### 3) A technical point: The role of correlations

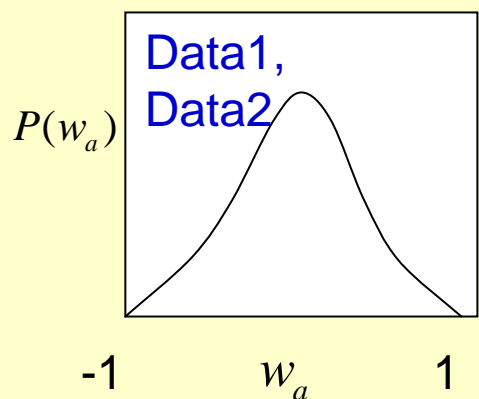


Our 8D space:  $q_i \in \{w_0, w_a, \Omega_{DE}, \Omega_k, \omega_m, \omega_B, n_s, \ln P\}$

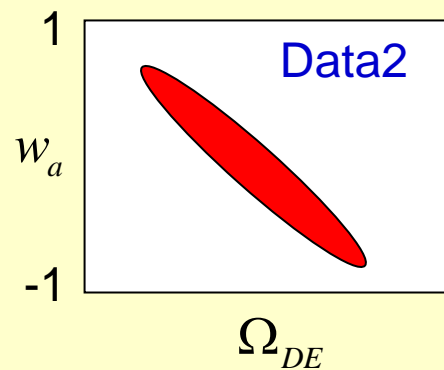
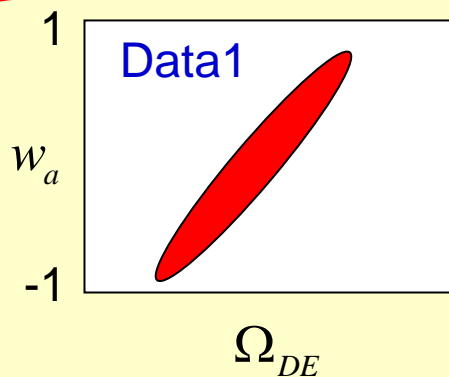
Q: Why 8D?

A: Correlations (in all 8D) are important. 2D illustration:

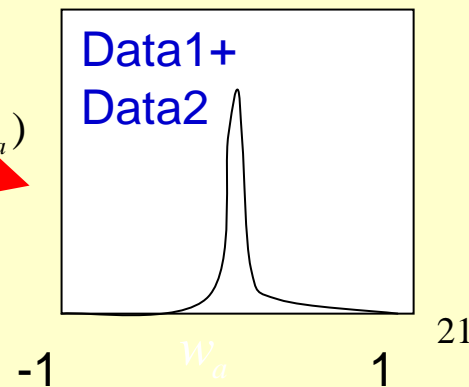
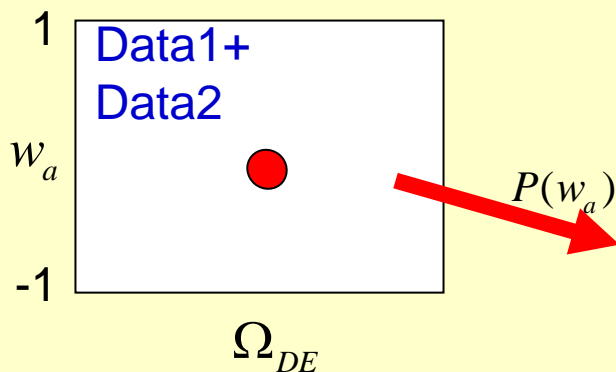
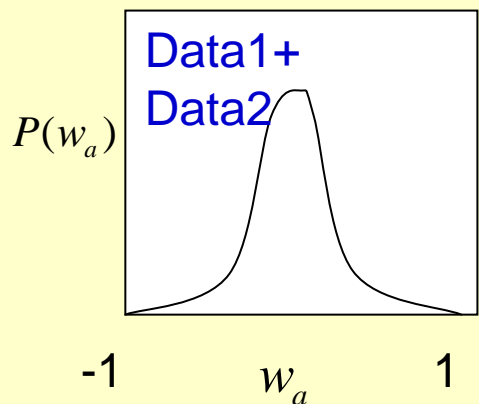
$w_a$  space only:



In higher D:



Combined Data1+Data2



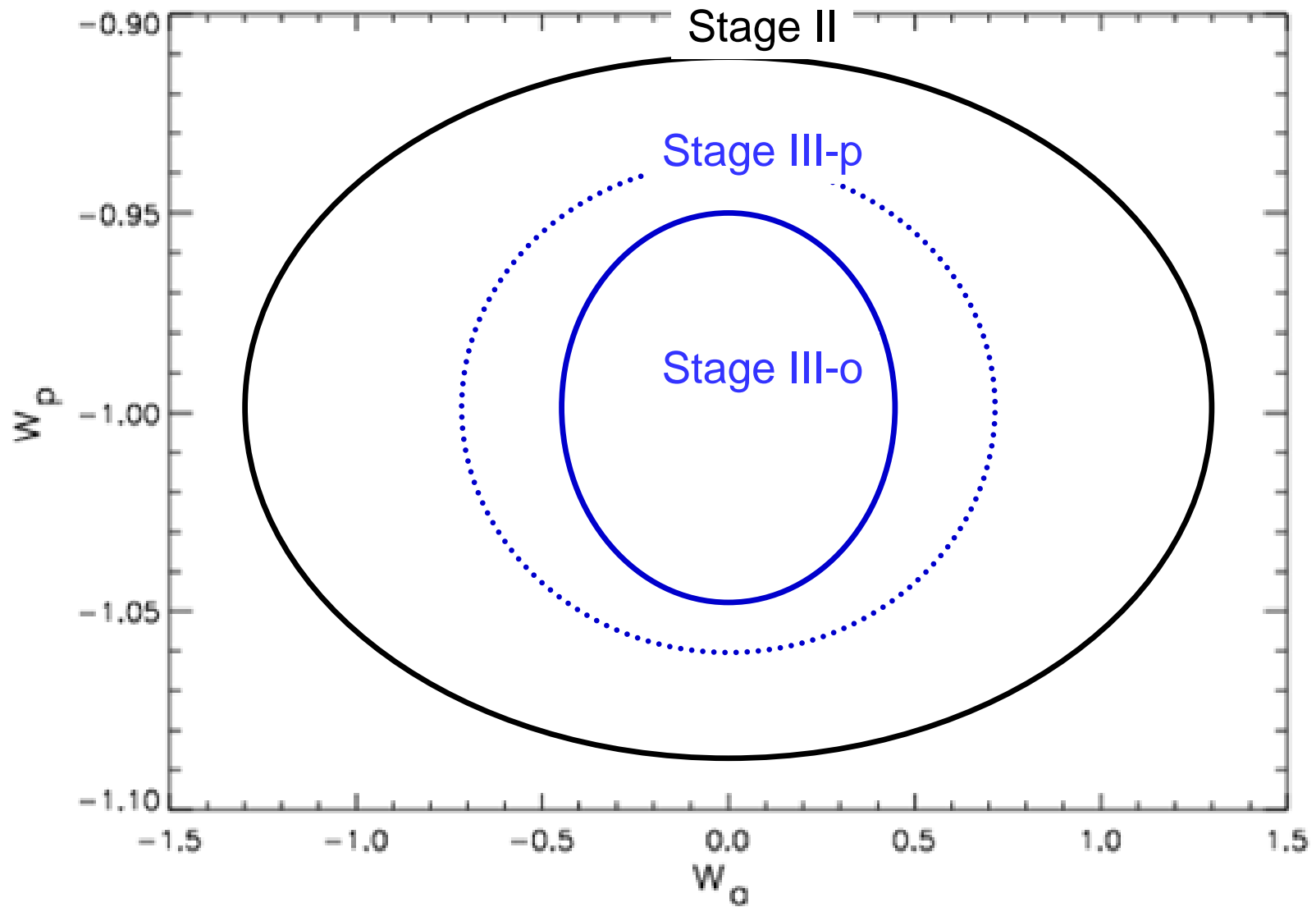
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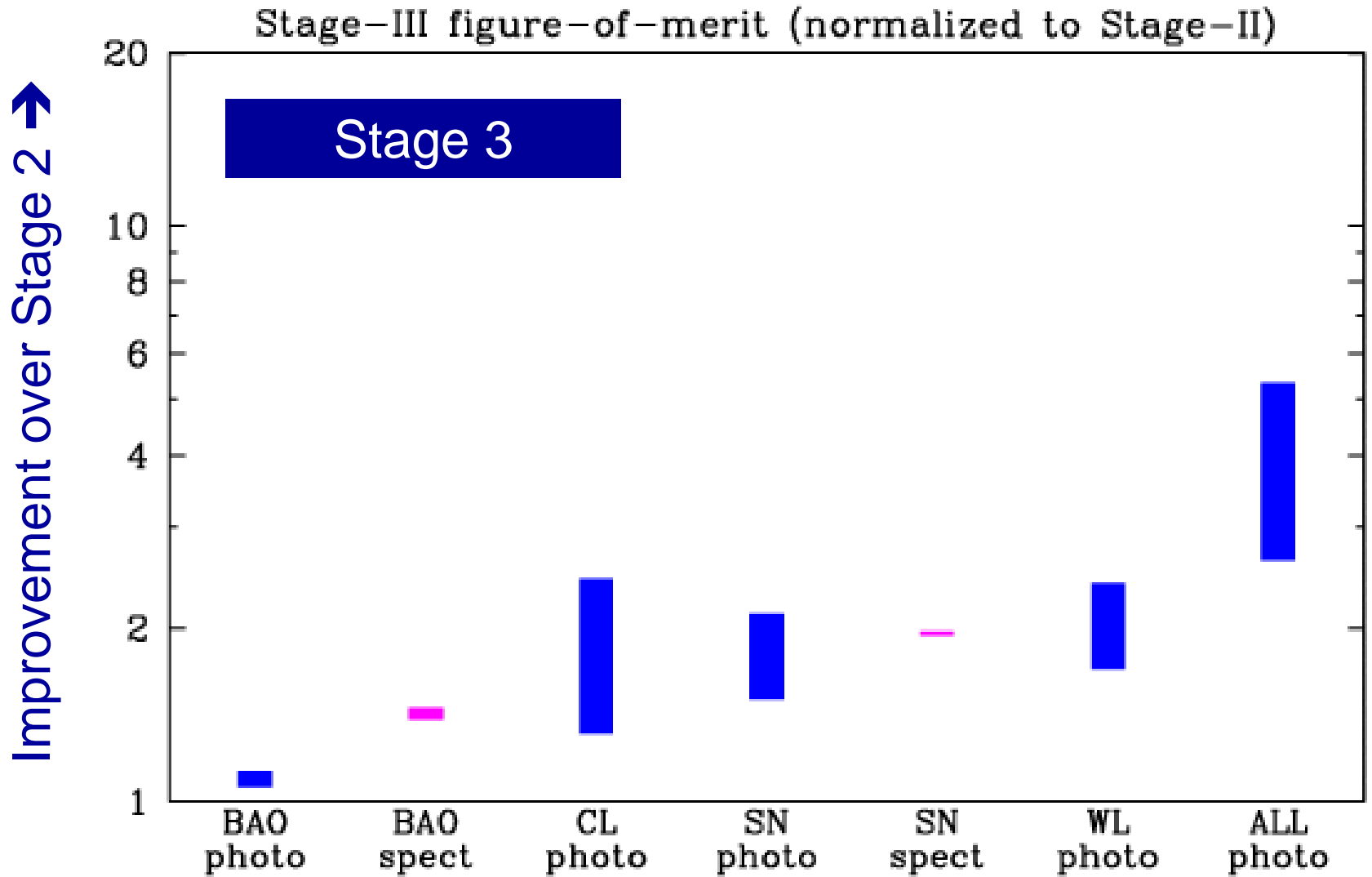
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# Combination of all techniques from a Stage-III photometric survey

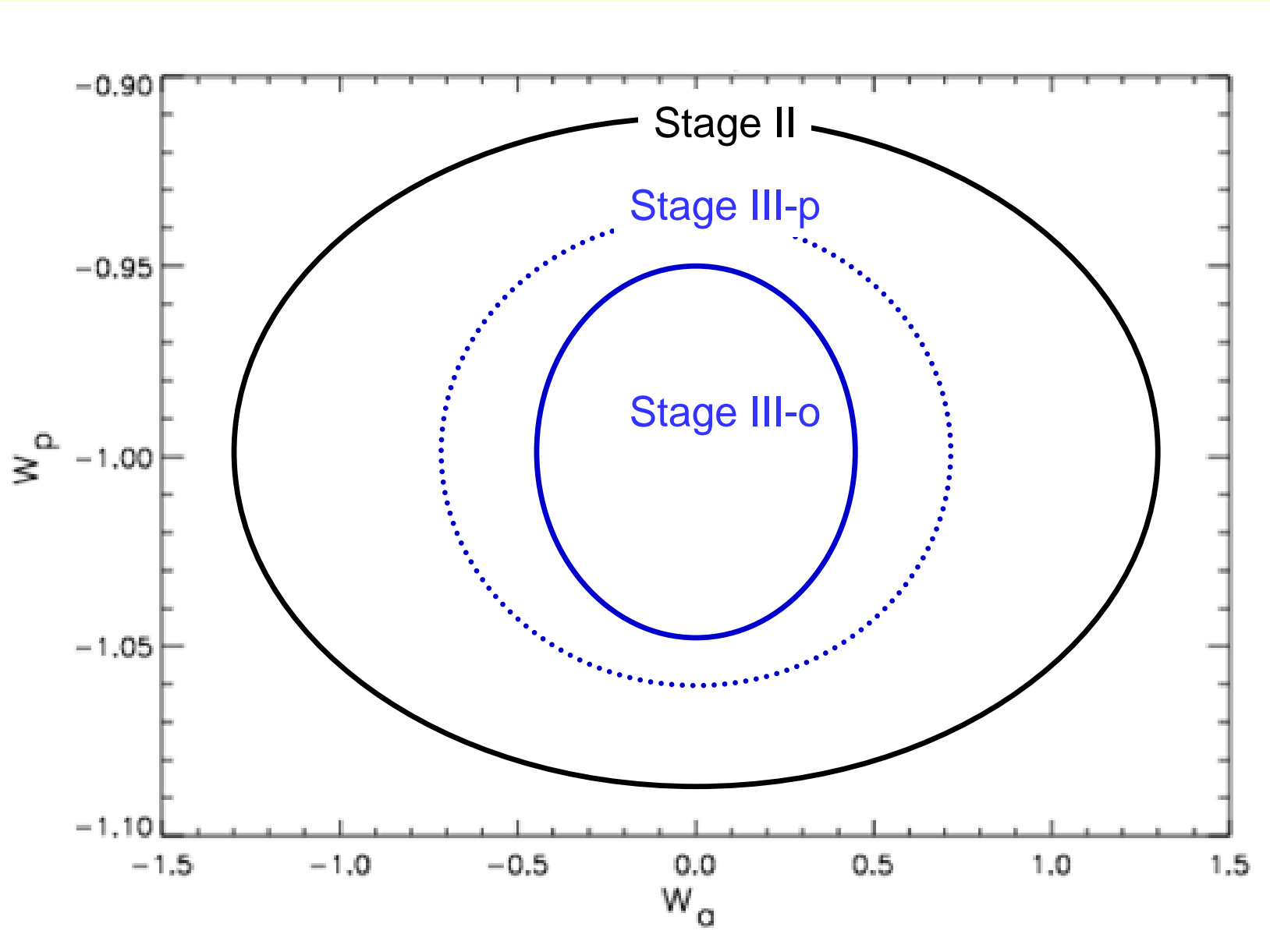


\* Pardon our mixed variables:  $W_p$ - $W_a$  and  $W_o$ - $W_a$  are equivalent (FoM-wise)

# DETF Projections

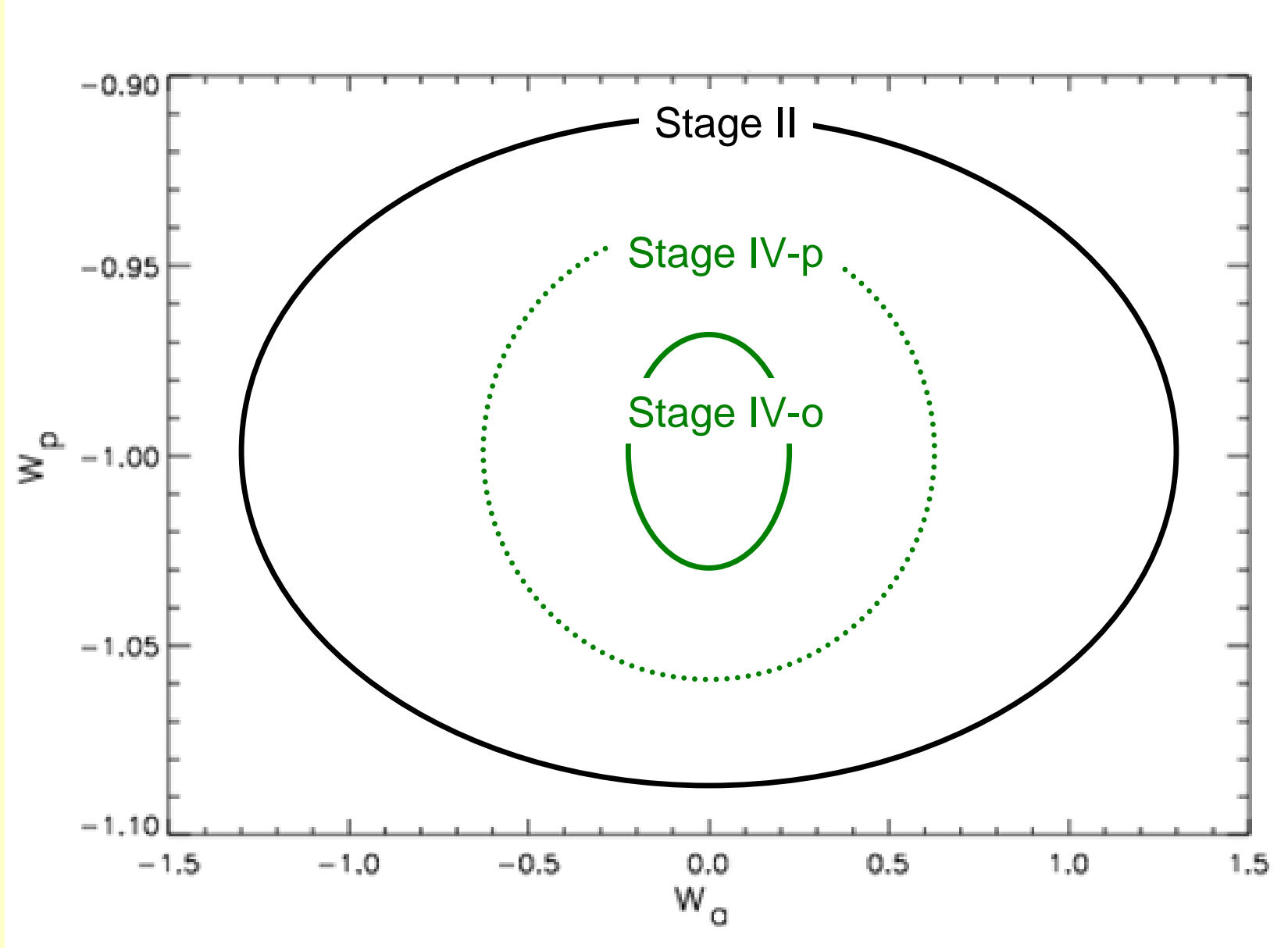


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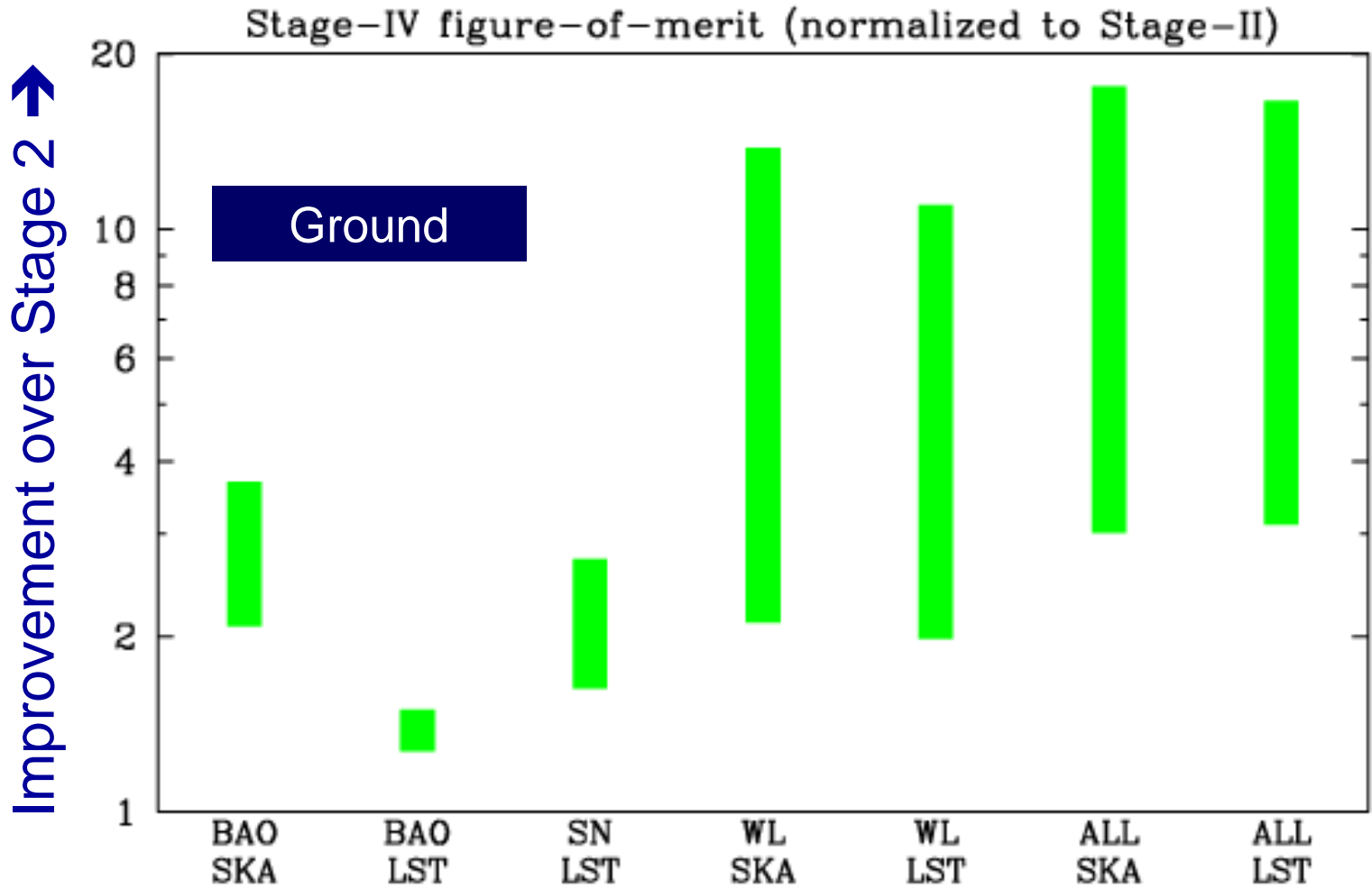


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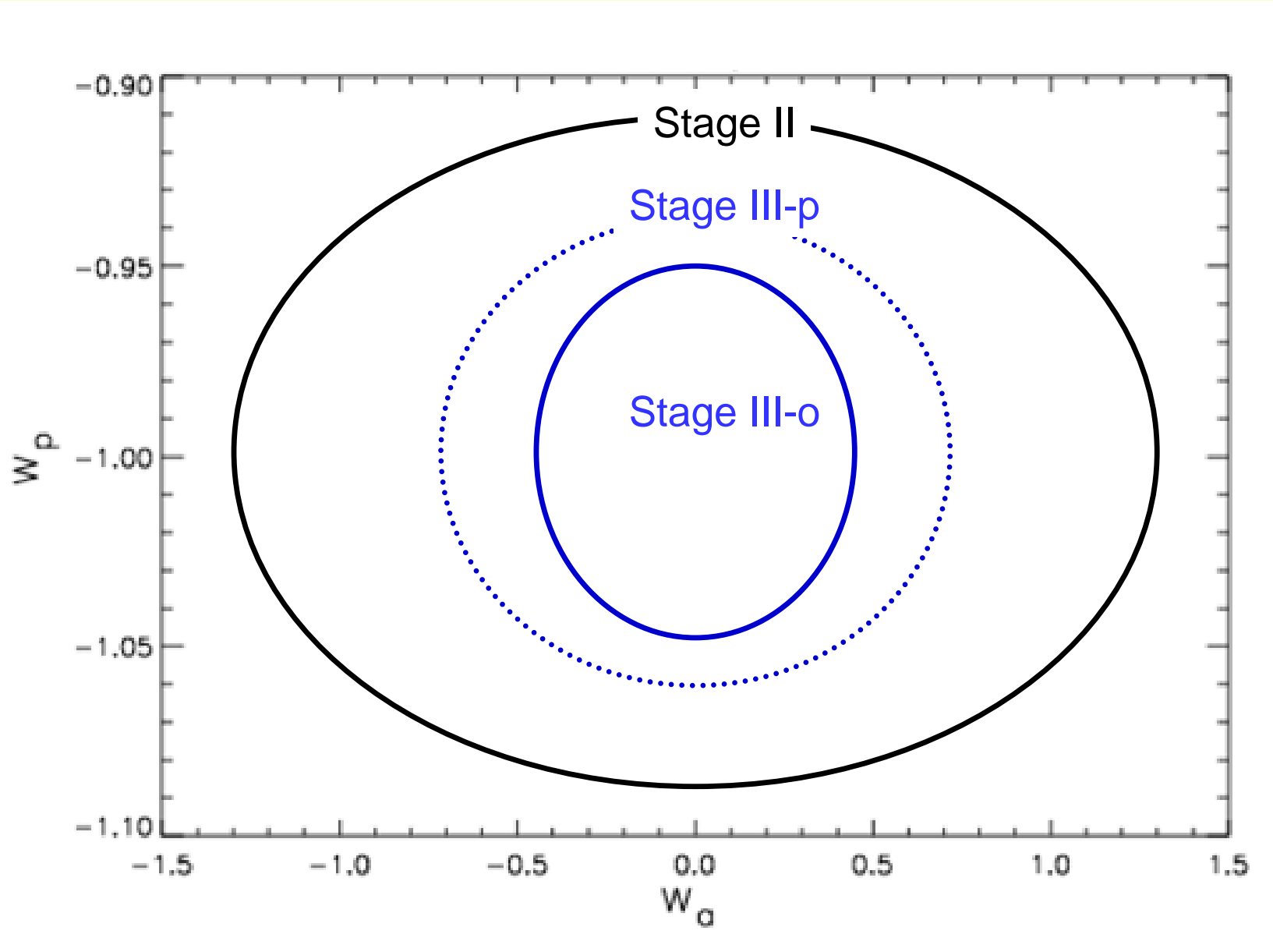
# Combination of all techniques from Stage-IV ground-based survey



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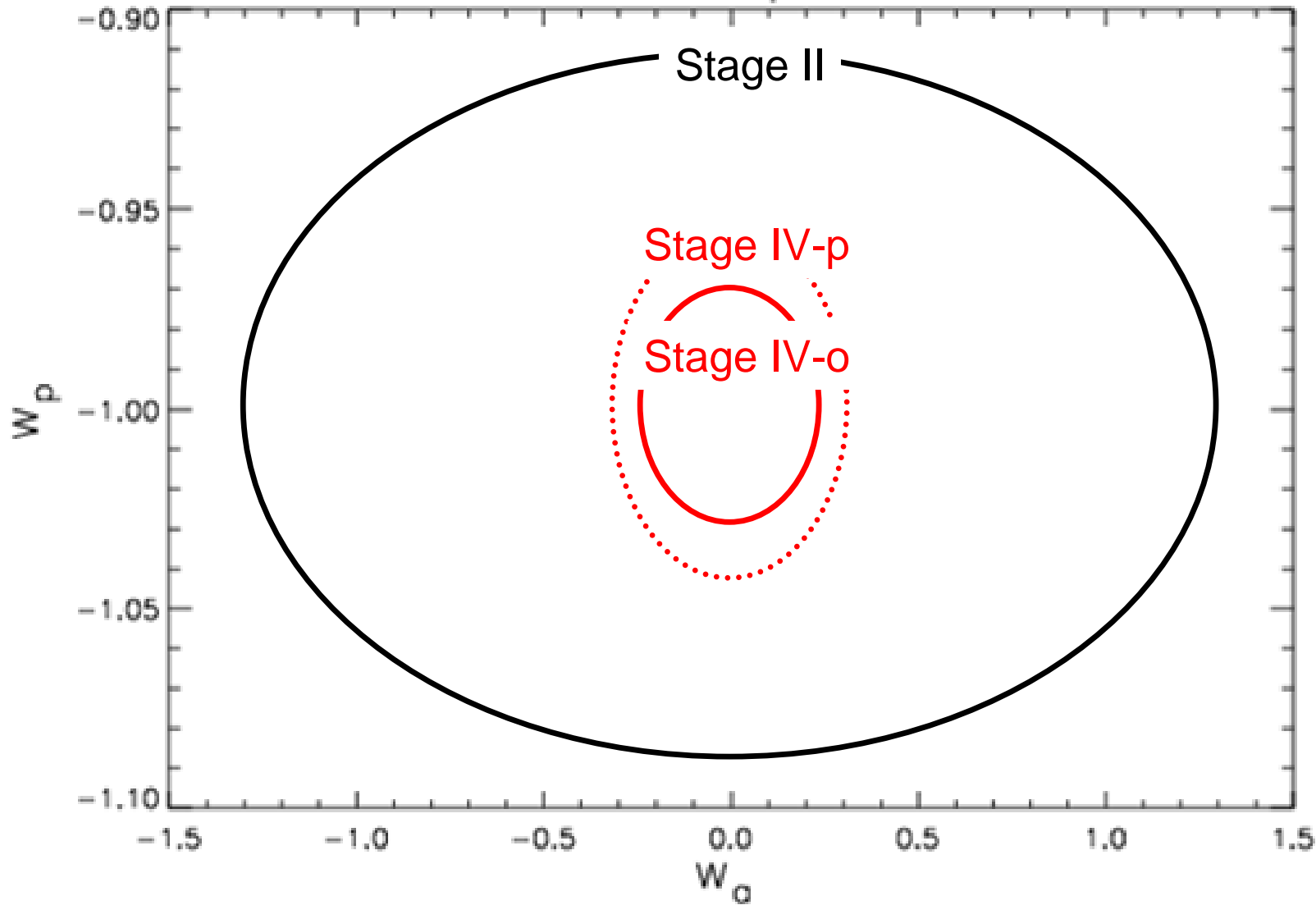


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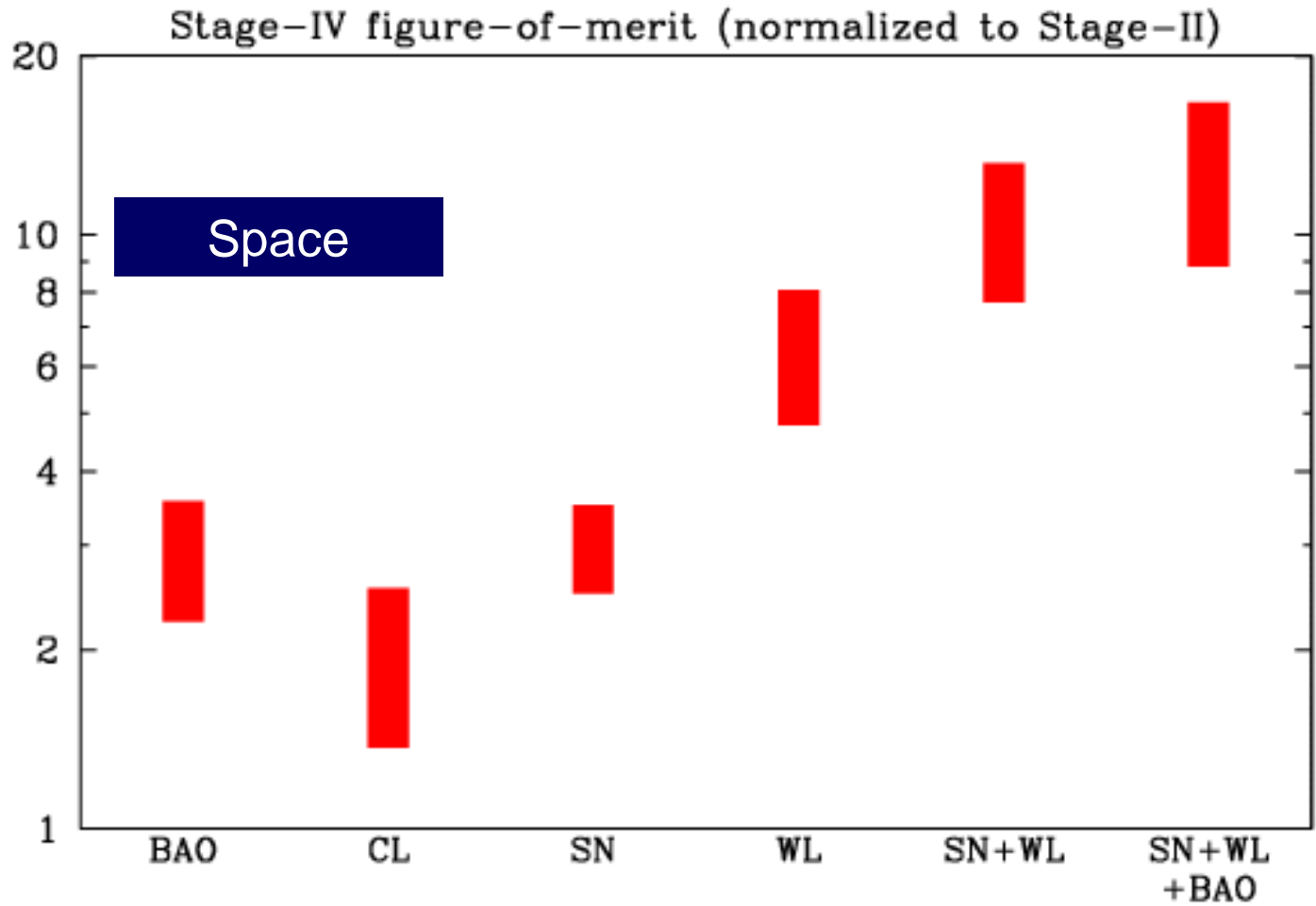
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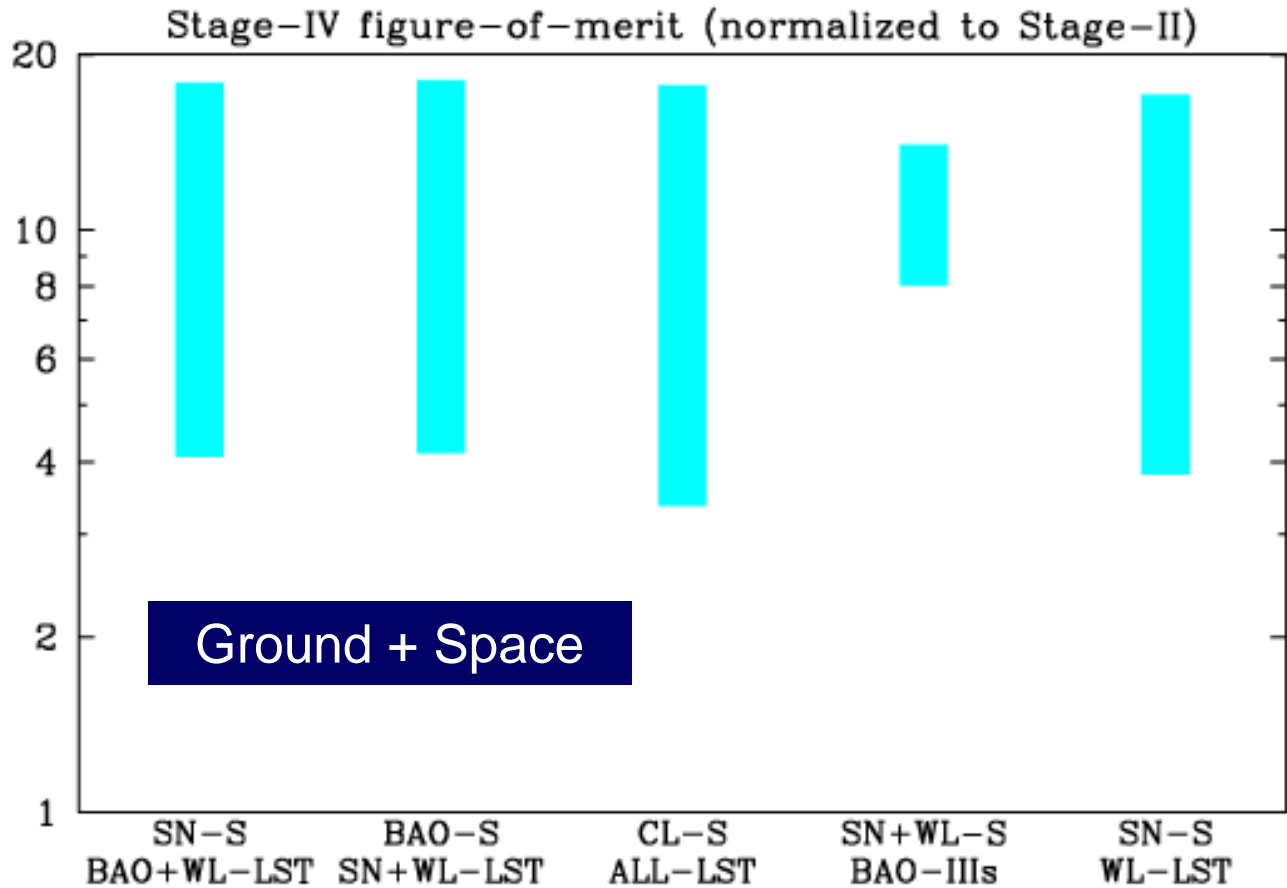
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## Key points:

- Our findings follow from our calculations
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- ➔  $\frac{1}{2}$  Order of magnitude improvement is possible at Stage 3
- ➔ 1 order of magnitude is possible at Stage 4
- ➔ Systematics are critical (as experts already knew)

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# **DETF Legacy**

## I. Standardization

1. Parameterize dark energy as  $w_0 - w_a$
2. Eight-parameter cosmological model
3. Priors
4. Figure of merit

## II. Importance of combinations

1. Soon will have a website with library of Fisher matrices & combiner programs

## III. DETF Technique Performance Projections

1. Thirty-two data models
2. Optimistic & pessimistic projections
3. Four techniques, two stages, five platforms

## IV. Use DETF Technique Performance Projections as a guideline!!!

1. We may be off-base (proposers must justify systematic-error budget!)
2. People get smarter

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We've done a lot of work.  
There's lots more to do!

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# Comments on the fundamental significance of Dark Energy

DE has already stimulated these radical new directions:

→ String theory landscape

→ “Universe as a finite entropy box”  $\leftrightarrow$  Fundamental physics as a finite dimensional Hilbert space

→ Particle theory mass scales of  $10^{-35} m_e$

→ etc

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DE has caused new pain from one of the deepest problems in fundamental physics: The cosmological constant problem.

is not “just another parameter”.

“Right now, not only for cosmology but for elementary particle theory, this is the **bone in our throat.**” - Steven Weinberg

“This is the biggest **embarrassment** in theoretical physics”  
- Michael Turner

“Basically, people **don't have a clue** as to how to solve this problem.” - Jeff Harvey

“... would be **No. 1 on my list** of things to figure out.”  
- Edward Witten

“... Maybe the **most fundamentally mysterious thing** in basic science.”  
- Frank Wilczek

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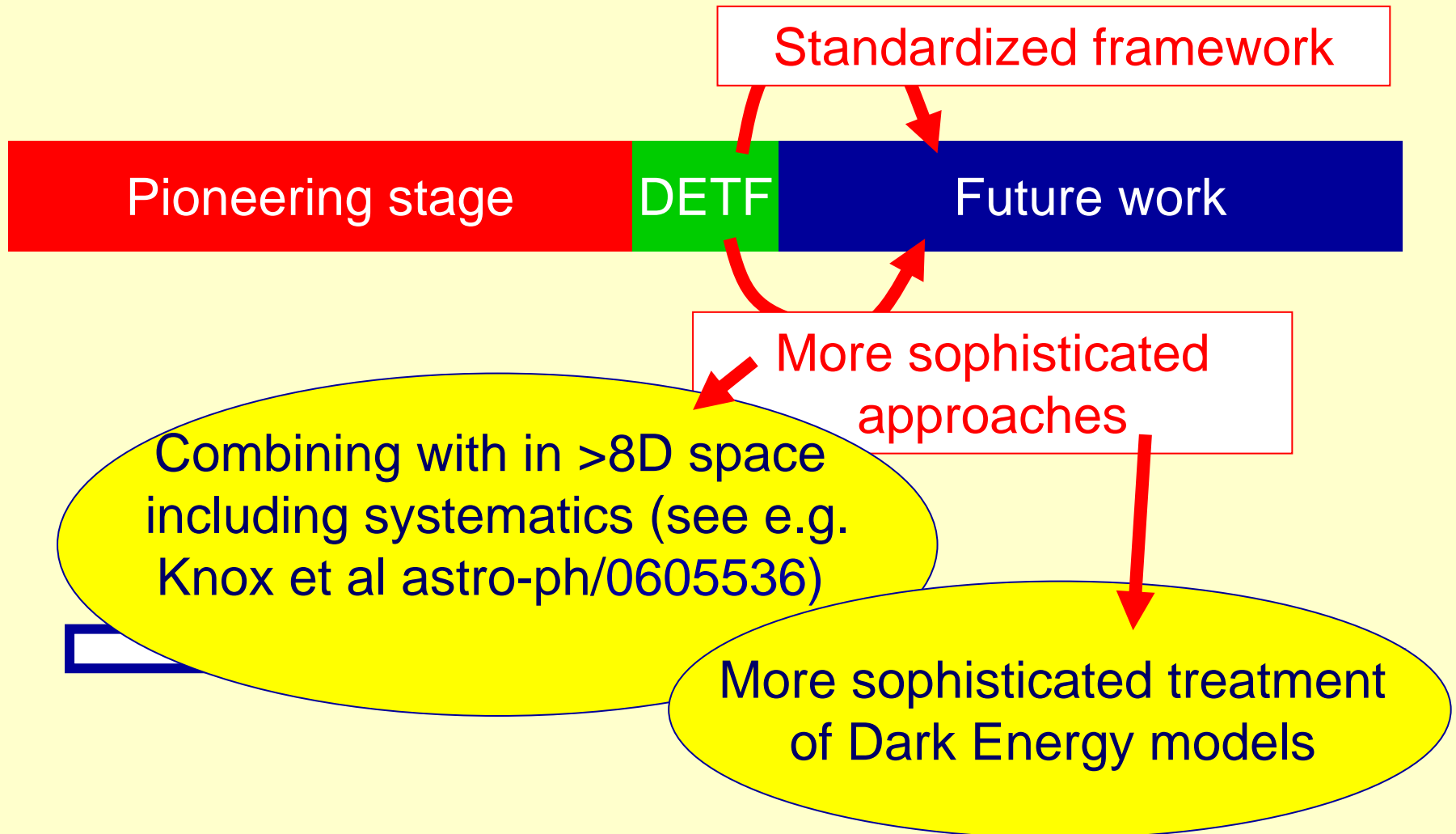
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## 7) Looking to the future

Our position in the dark energy timeline



Dark energy appears to be the dominant component of the physical Universe, yet there is no persuasive theoretical explanation. The acceleration of the Universe is, along with dark matter, the observed phenomenon which most directly demonstrates that our fundamental theories of particles and gravity are either incorrect or incomplete. Most experts believe that nothing short of a revolution in our understanding of fundamental physics will be required to achieve a full understanding of the cosmic acceleration. For these reasons, the nature of dark energy ranks among the very most compelling of all outstanding problems in physical science. These circumstances demand an ambitious observational program to determine the dark energy properties as well as possible.

END