Dark Energy Task Force

Nicholas Suntzeff
Texas A&M
15 September 2006

Texas Cosmology Network Meeting

Dark Energy Task Force (DETF)

http://www.nsf.gov/mps/ast/detf.jsp

• Three agencies:	DOE; NASA; NSF
• Two subcommittees:	AAAC (Illingworth); HEPAP (Shochet)
• Two charge letters:	Kinney (NASA); Staffin (DOE); Turner (NSF)
• Twelve members:	Overlap with AAAC, HEPAP, SDT
• One chair:	Rocky Kolb (Fermilab/Chicago)

DETF Membership

- Members
  Andy Albrecht, Davis
  Gary Bernstein, Penn
  Bob Cahn, LBNL
  Wendy Freedman, OCIW
  Jackie Hewitt, MIT
  Wayne Hu, Chicago
  John Huth, Harvard
  Mark Kamionkowski, Caltech
  Rocky Kolb, Fermilab/Chicago
  Lloyd Knox, Davis
  John Mather, GSFC
  Suzanne Staggs, Princeton
  Nick Suntzeff, NOAO

- Agency Representatives
  - DOE: Kathy Turner
  - NASA: Michael Salamon
  - NSF: Dana Lehr

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• Face Meetings:	March 22–23, 2005	@ NSF
	June 30–July1, 2005	@ Fermilab
	October 19–21, 2005	@ Davis
	December 7–8, 2005	@ MIT

- Friday phonecons
- More than 10^3 email messages
- Fifty "White Papers" solicited from Community

Dark Energy Task Force Charge*

"The DETF is asked to advise the agencies on the optimum† near and intermediate-term programs to investigate dark energy and, in cooperation with agency efforts, to advance the justification, specification and optimization of LST and JDEM."

1. Summarize existing program of funded projects
2. Summarize proposed and emergent approaches
3. Identify important steps, precursors, R&D, …
4. Identify areas of dark energy parameter space existing or proposed projects fail to address
5. Prioritize approaches (not projects)

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* Fair range of interpretations of charge.

† Optimum ≡ minimum (agencies); Optimum ≡ maximal (community)

Dark Energy Task Force Report

I. Context:

- The issue: acceleration of the Universe
- Possibilities: dark energy (Λ or not), non-GR
- Motivation for future investigations

II. Goals and Methodology:

- Goal of dark energy investigations
- Methodology to analyze techniques/implementations

III. Findings:

- Techniques (largely from White Papers)
- Implementations (largely from White Papers)
- Systematic uncertainties
- What we learned from analysis

IV. Recommendations:

V. Technical appendices

Context

1. Conclusive evidence for acceleration of the Universe.
   Standard cosmological framework → dark energy (70% of mass-energy).
2. Possibility: Dark Energy constant in space & time (Einstein's Λ).
3. Possibility: Dark Energy varies with time (or redshift z or $a = (1+z)^{-1}$).
4. Impact of dark energy can be expressed in terms of "equation of state" $w(a) = p(a) / \rho(a)$ with $w(a) = -1$ for Λ.
5. Possibility: GR or standard cosmological model incorrect.
6. Whatever the possibility, exploration of the acceleration of the Universe will profoundly change our understanding of the composition and nature of the Universe.

Context

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.

Goals and Methodology

4. To quantify progress in measuring properties of dark energy we define dark energy figure-of-merit from combination of uncertainties in w_0 and w_a. (Caveat.)
5. We made extensive use of statistical (Fisher-matrix) techniques incorporating CMB and H_0 information to predict future performance (100 models).
6. Our considerations follow developments in Stages:
   I. What is known now (2/2006).
   II. Anticipated state upon completion of ongoing projects.
   III. Near-term, medium-cost, currently proposed projects.
   IV. Large-Survey Telescope (LST) and/or Square Kilometer Array (SKA), and/or Joint Dark Energy (Space) Mission (JDEM).
7. Dark-energy science has far-reaching implications for other fields of physics $\rightarrow$ discoveries in other fields may point the way to understanding nature of dark energy (*e.g.*, evidence for modification of GR).

Fermilab

Fermi National Accelerator Laboratory
Particle Astrophysics Center
P.O.Box 500 - MS209
Batavia, Illinois • 60510

June 6, 2006

Dr. Garth Illingworth
Chair, Astronomy and Astrophysics Advisory Committee
Dr. Mel Shochet
Chair, High Energy Physics Advisory Panel

Dear Garth, Dear Mel,

I am pleased to transmit to you the report of the Dark Energy Task Force.

The report is a comprehensive study of the dark energy issue, perhaps the most compelling of all outstanding problems in physical science. In the Report, we outline the crucial need for a vigorous program to explore dark energy as fully as possible since it challenges our understanding of fundamental physical laws and the nature of the cosmos.

We recommend that program elements include

1. Prompt critical evaluation of the benefits, costs, and risks of proposed long-term projects.
2. Commitment to a program combining observational techniques from one or more of these projects that will lead to a dramatic improvement in our understanding of dark energy. (A quantitative measure for that improvement is presented in the report.)
3. Immediately expanded support for long-term projects judged to be the most promising components of the long-term program.
4. Expanded support for ancillary measurements required for the long-term program and for projects that will improve our understanding and reduction of the dominant systematic measurement errors.
5. An immediate start for nearer term projects designed to advance our knowledge of dark energy and to develop the observational and analytical techniques that will be needed for the long-term program.

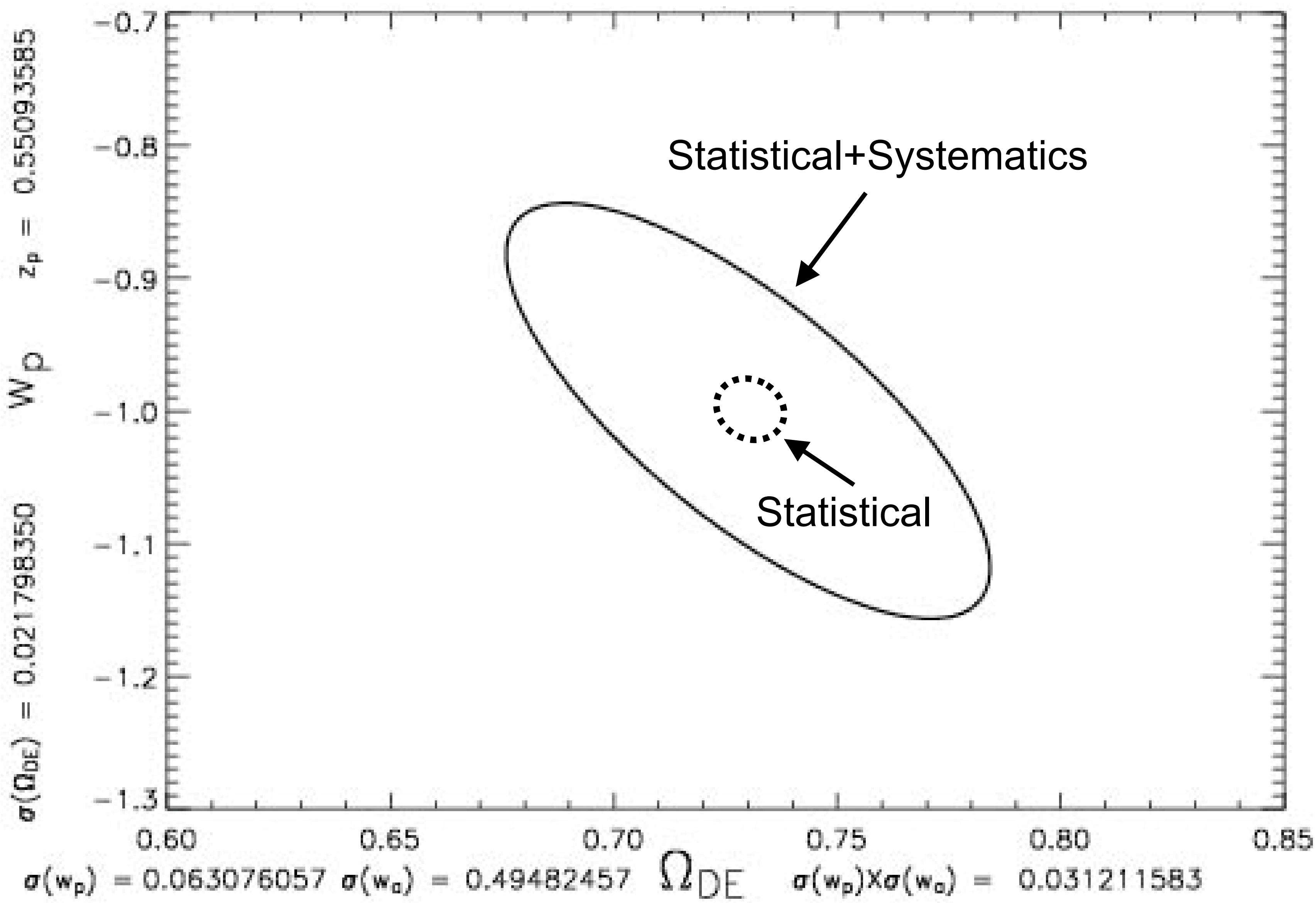
Sincerely yours, on behalf of the Dark Energy Task Force,

Rocky

Edward Kolb
Director, Particle Astrophysics Center
Fermi National Accelerator Laboratory
Professor of Astronomy and Astrophysics
The University of Chicago

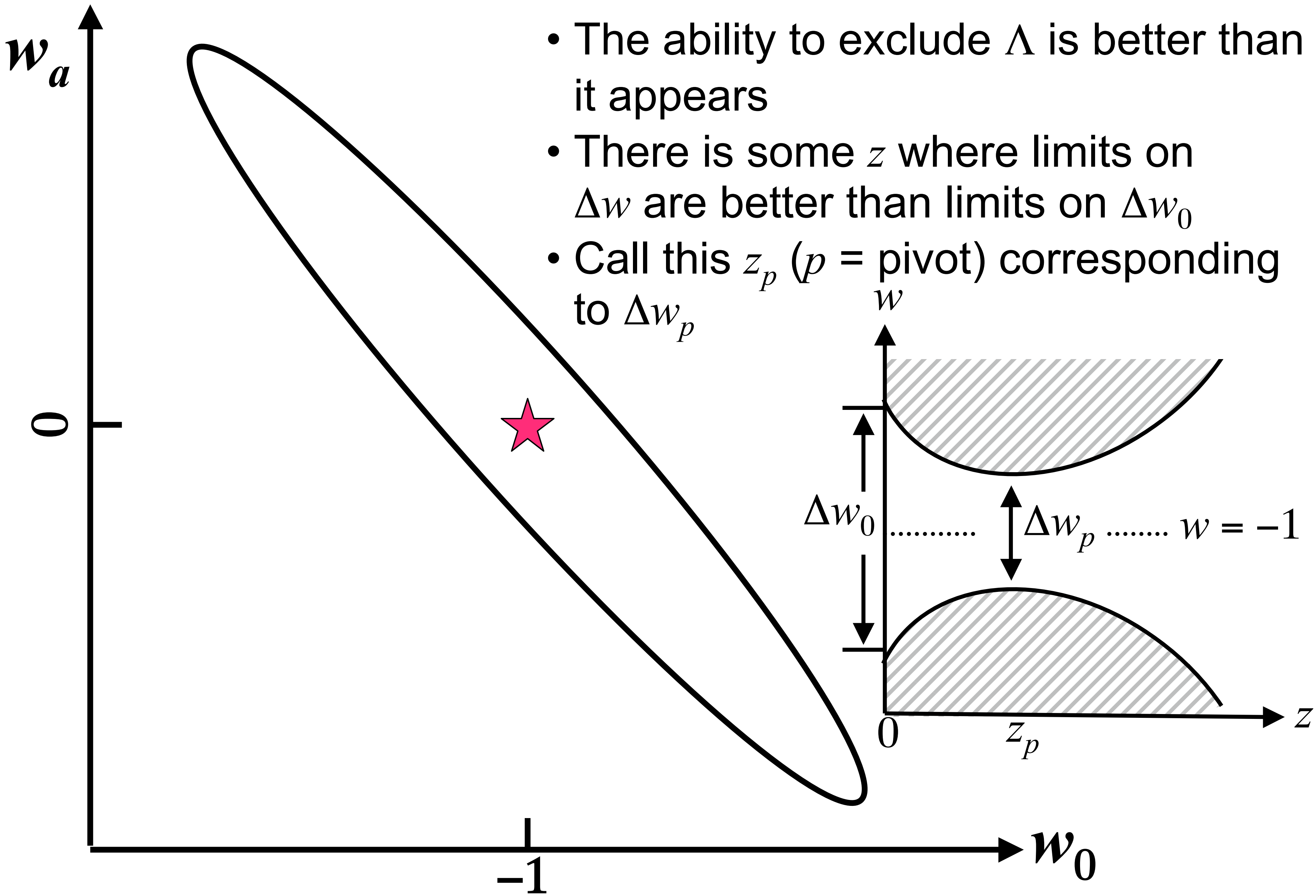
Systematics, Systematics, Systematics

A sample WL fiducial model

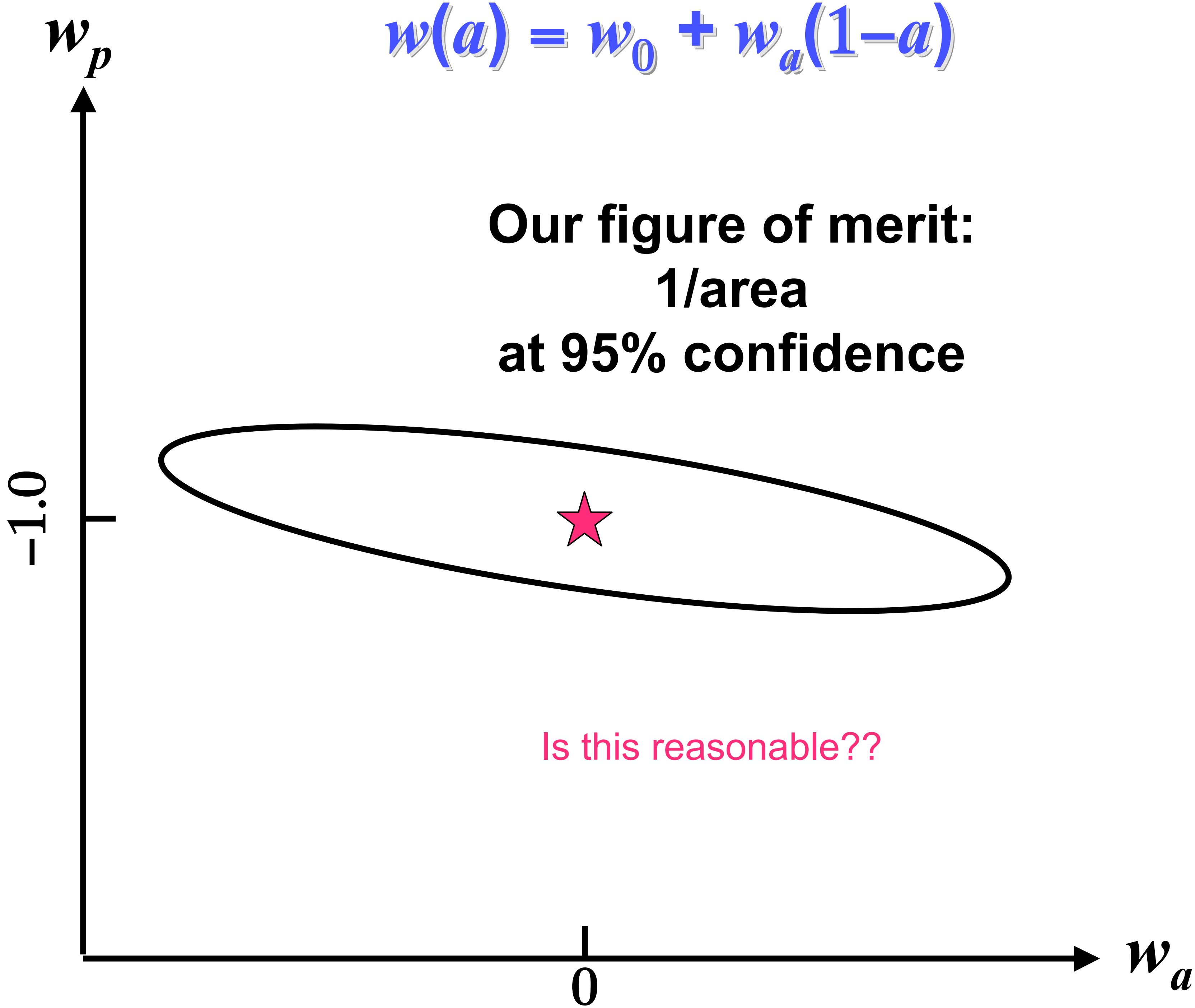


$w(a) = w_0 + w_a(1-a)$

- The ability to exclude Λ is better than it appears
- There is some z where limits on Δw are better than limits on Δw_0
- Call this z_p (p = pivot) corresponding to Δw_p

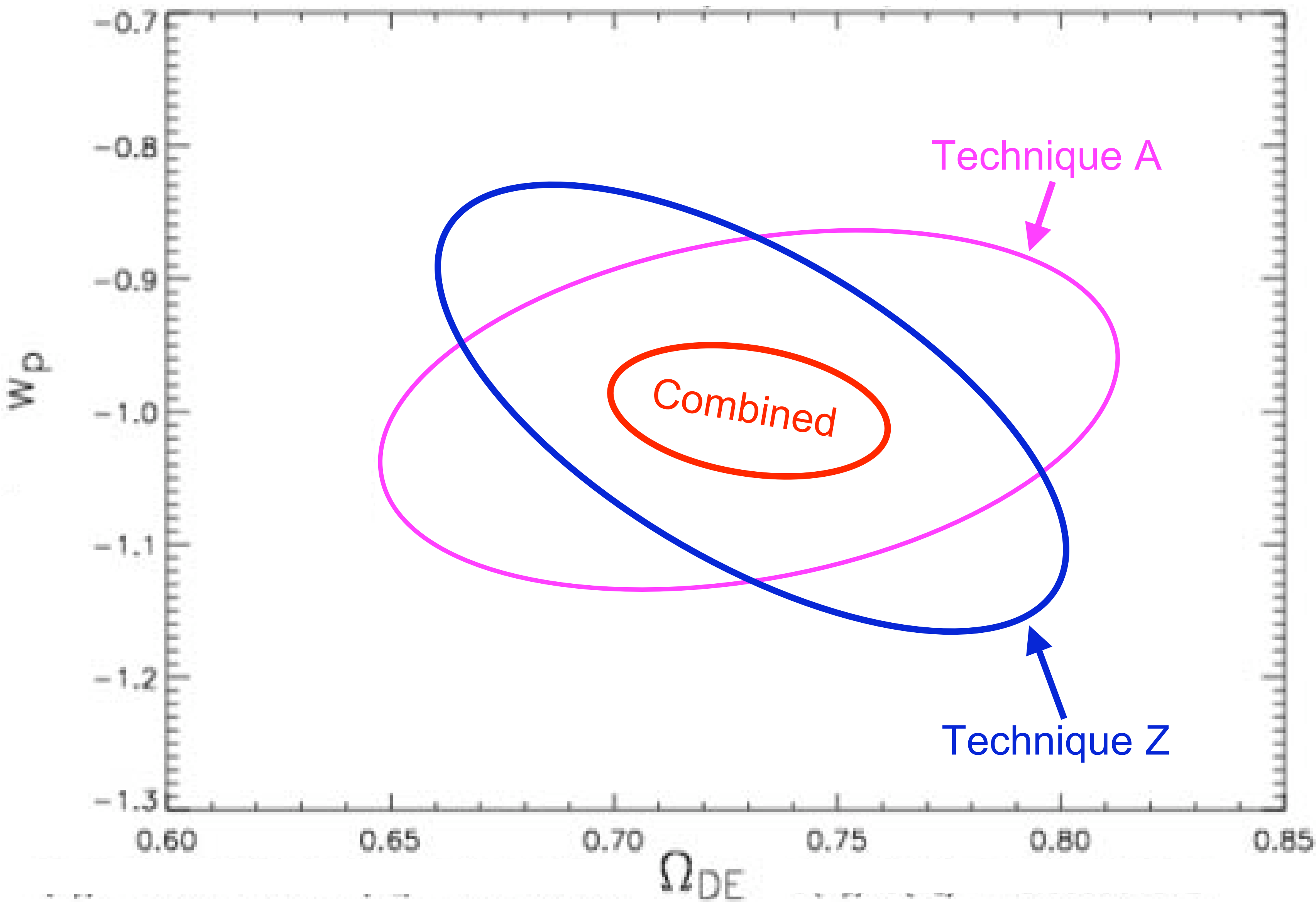


$$w(a) = w_0 + w_a(1-a)$$

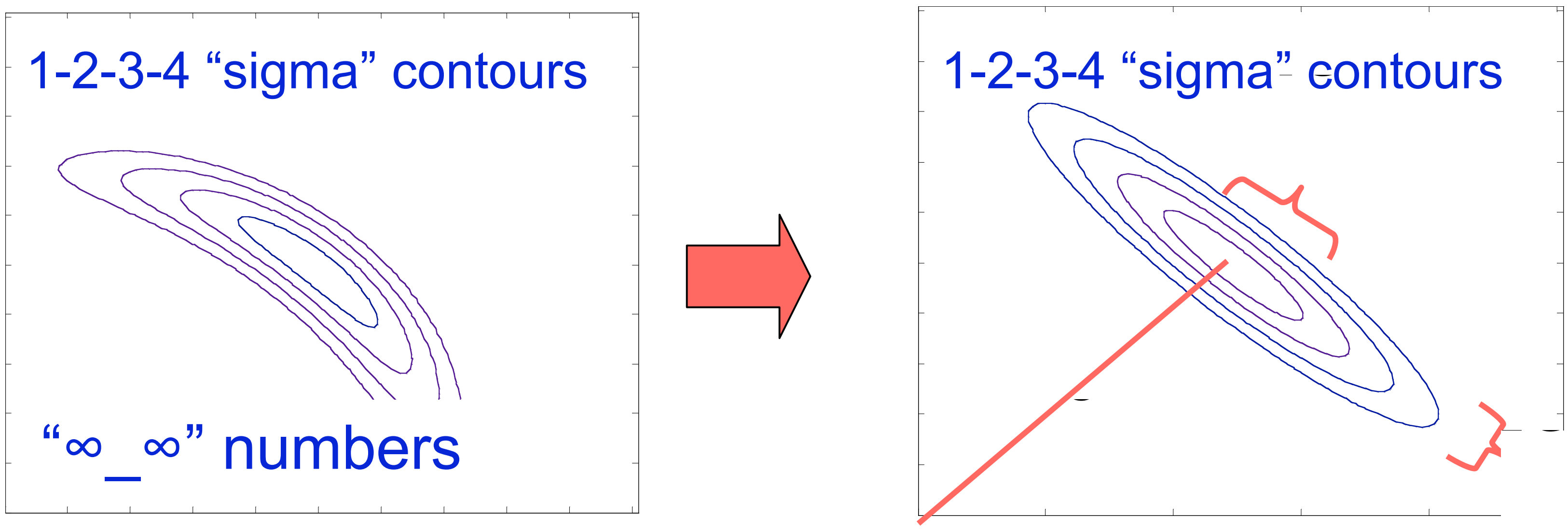

w_p
-1.0
Our figure of merit:
1/area
at 95% confidence
Is this reasonable??
0
w_a

The Power of Two (or Three, or Four)

$\sigma(w_p) \times \sigma(w_a) = 0.04$ $\sigma(w_p) \times \sigma(w_a) = 0.009$ $\sigma(w_p) \times \sigma(w_a) = 0.05$



2) Basic Fisher Matrix Tools



3 numbers

Inverse covariance matrix represents
data on observables

2) Basic Fisher Matrix Tools

i) Having mapped into the natural parameter space for calculations equations, we make another transformation:

Basic conclusions

- Determine if acceleration is _
- Measure time evolution of dark energy
- Search for failure of GR
  - Compare acceleration effects with growth of structure
  - Theoretical studies

Summary of DETF recommendations:

I. We strongly recommend that there be an aggressive program to explore dark energy as fully as possible, since it challenges our understanding of fundamental physical laws and the nature of the cosmos.

II. We recommend that the dark energy program have multiple techniques at every stage, at least one of which is a probe sensitive to the growth of cosmological structure in the form of galaxies and clusters of galaxies.

III. We recommend that the dark energy program include a combination of techniques from one or more Stage III projects designed to achieve, in combination, at least a <u>factor of three</u> gain over Stage II in the DETF figure of merit, based on critical appraisals of likely statistical and systematic uncertainties.

IV. We recommend that the dark energy program include a combination of techniques from one or more Stage IV projects designed to achieve, in combination, at least a <u>factor of ten</u> gain over Stage II in the DETF figure of merit, based on critical appraisals of likely statistical and systematic uncertainties. Because JDEM, LST, and SKA all offer promising avenues to greatly improved understanding of dark energy, we recommend continued research and development investments to optimize the programs and to address remaining technical questions and systematic-error risks.

V. We recommend that high priority for near-term funding should be given as well to projects that will improve our understanding of the dominant systematic effects in dark energy measurements and, wherever possible, reduce them, even if they do not immediately increase the DETF figure of merit.

VI. We recommend that the community and the funding agencies develop a coherent program of experiments designed to meet the goals and criteria set out in these recommendations.

The four techniques

- Baryon acoustic oscillations
- Supernovae
- Galaxy clustering
- Weak lensing

Stage III x3, Stage IV x10 for two or more techniques

Growth + acceleration tests

My minority opinion

- $w = -1 \pm \_$. What is _??
- As $w \rightarrow -1$, is w_a important?
- Dark energy, dark matter, baryon asymmetry
- Hubble constant & Hubble bubbles
- Photo-z's, photometry, Vega/WD, filters
- All experiments are $(N)^{1/2}$ - this should be a warning that nimble experiments may upstage the large projects.

Astronomy at Texas A & M

- my goal - > 12 astronomy faculty
- Giant Magellan Telescope
- Create undergraduate and graduate curriculum at A&M – Kevin Krisciunas
- Instrumentation program
- Stage III projects – HETDEX, LSST, PANStarrs, SDSSIII, DEC, 4m SPT, FLASH, …
- 2 hires this year