SNAP SuperNova Acceleration Probe

Presentation to the NRC's Committee on Astronomy & Astrophysics

December 5, 2000

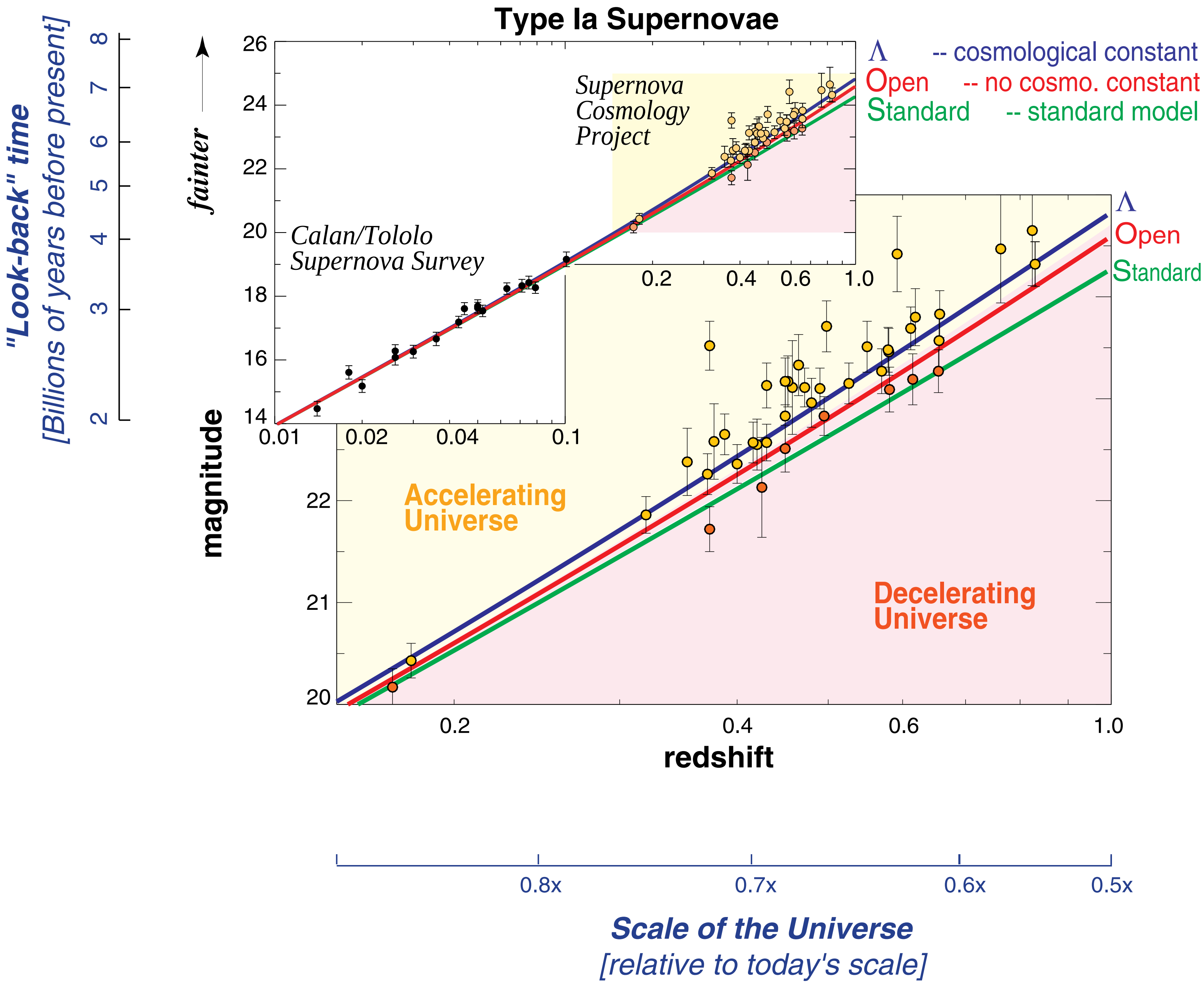
Saul Perlmutter

SuperNova / Acceleration Probe (SNAP)

An Experiment to Measure the Properties of the Dark Energy of the Universe

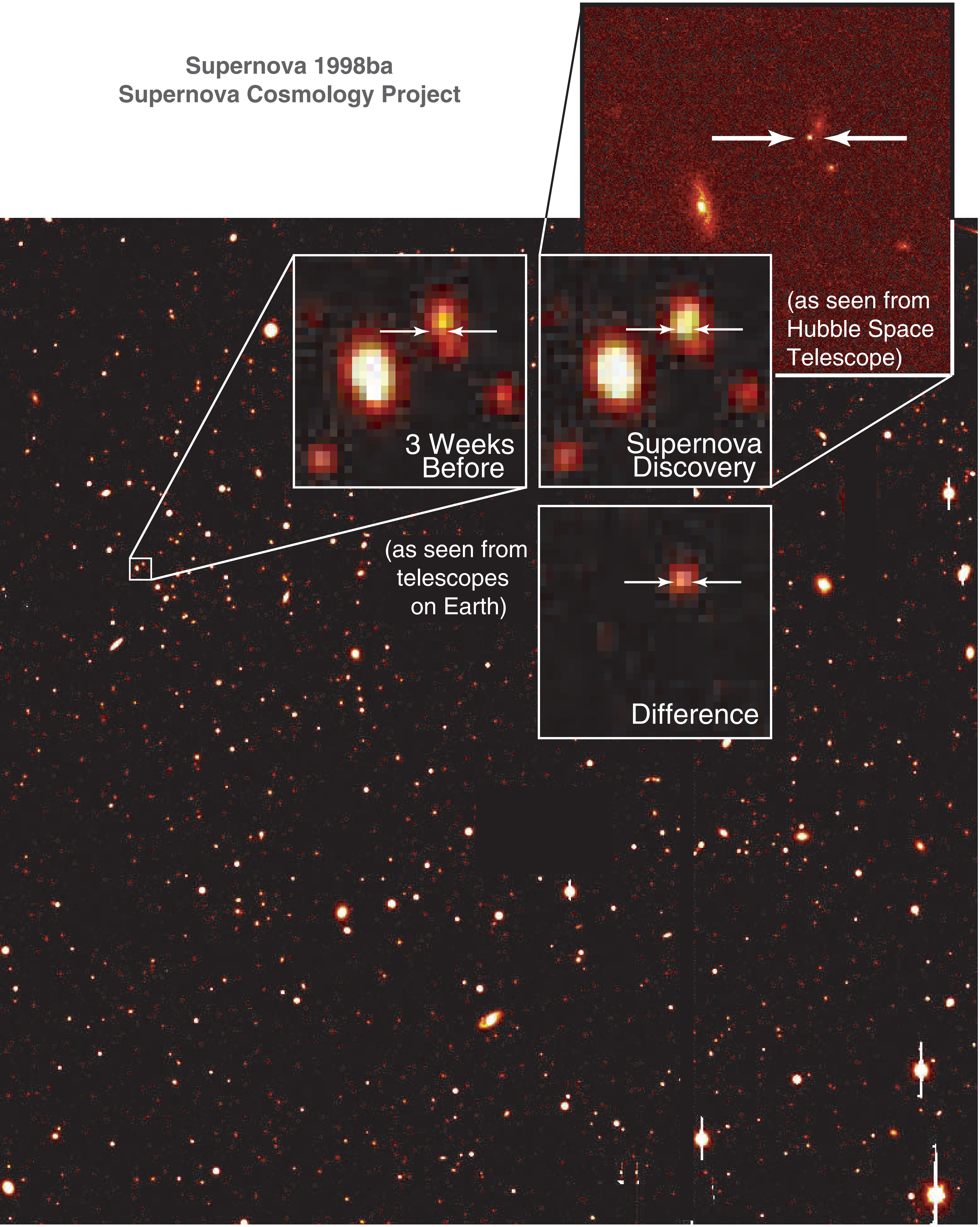
The Institutions of the SNAP Collaboration

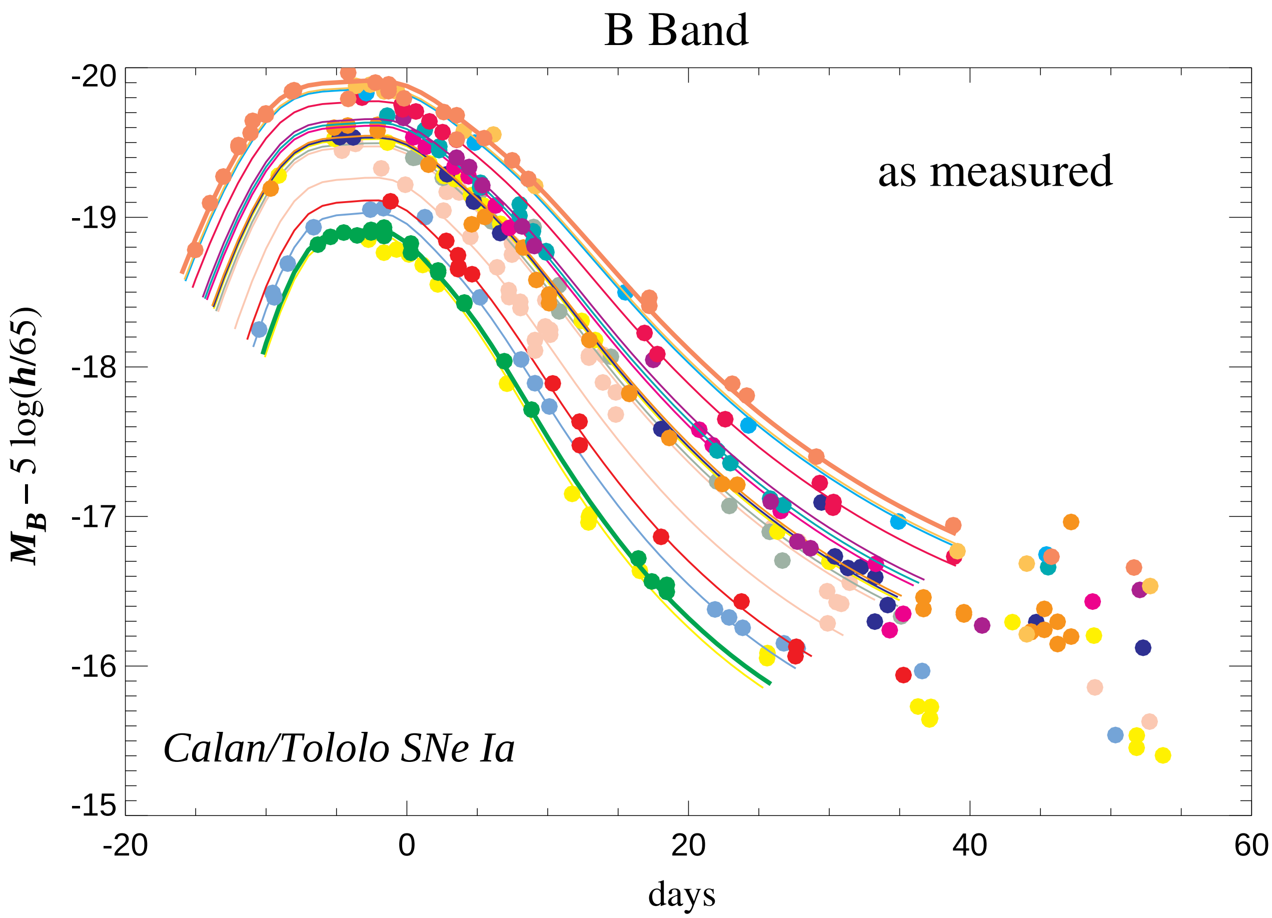
University of California, Berkeley
Lawrence Berkeley National Laboratory
CNRS-IN2P3, LPNHE, and University Paris VI & VII
University of Maryland, College Park, MD
Cornell University
University of Chicago
Space Telescope Sciences Institute
California Institute of Technology
CEA/DAPNIA, Saclay, France
Gemini Observatory
European Southern Observatory
University of Stockholm
University of Lisbon

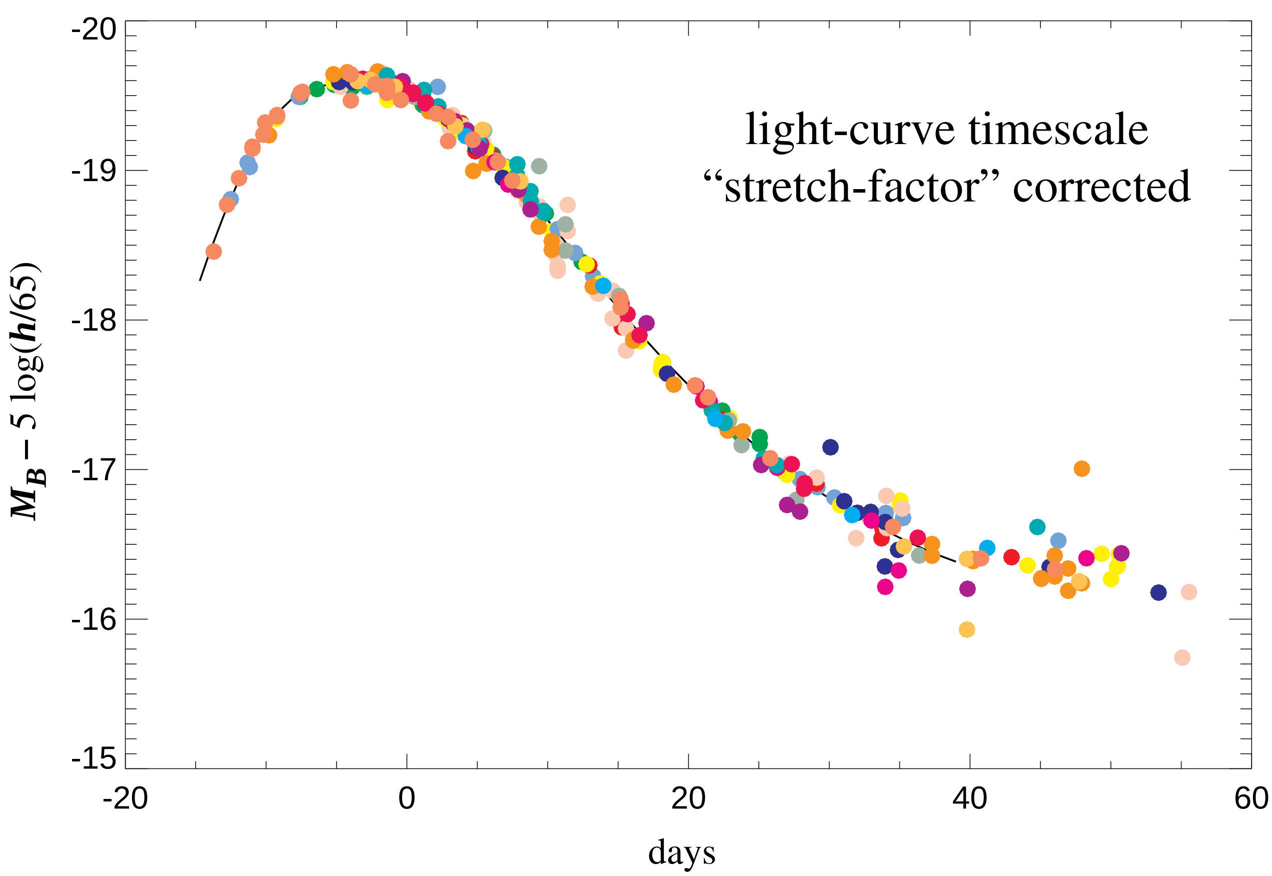


Type Ia Supernovae
Λ -- cosmological constant
Open -- no cosmo. constant
Standard -- standard model
Supernova Cosmology Project
Calan/Tololo Supernova Survey
fainter
magnitude
redshift
Accelerating Universe
Decelerating Universe
Λ
Open
Standard
"Look-back" time
[Billions of years before present]
Scale of the Universe
[relative to today's scale]
0.8x
0.7x
0.6x
0.5x

Supernova 1998ba
Supernova Cosmology Project







Kim, *et al.* (1997)

The implications of an accelerating universe:

1. The expansion is not slowing to a halt and then collapsing (i.e., the universe is *not* "coming to an end"). In the simplest models, it will expand forever.

2. There is a previously unseen energy pervading all of space that accelerates the universe's expansion.

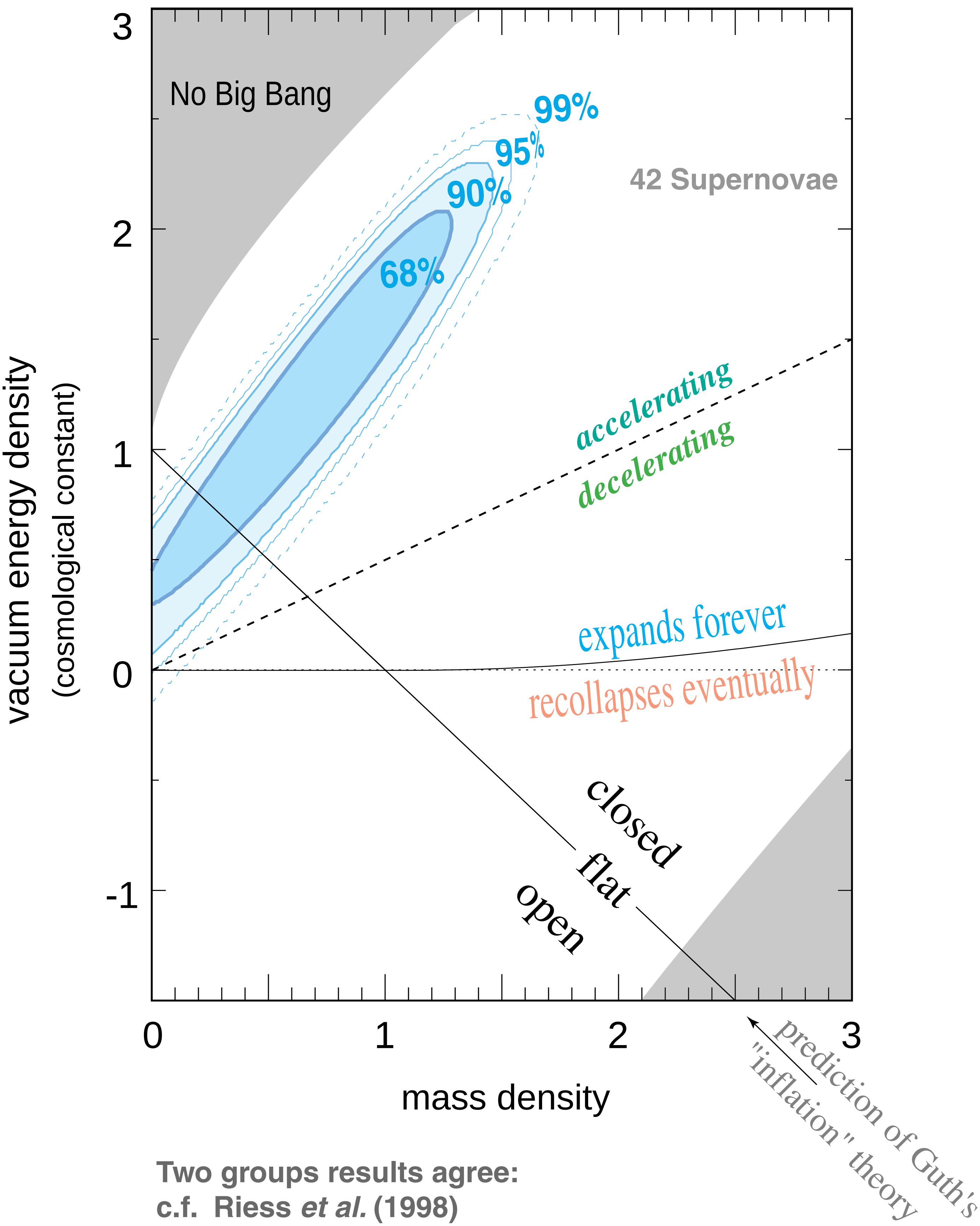
   This new accelerating energy ("dark energy") has a larger energy density than the mass density of the universe (or else the universe's expansion wouldn't be accelerating).

What we don't know is:

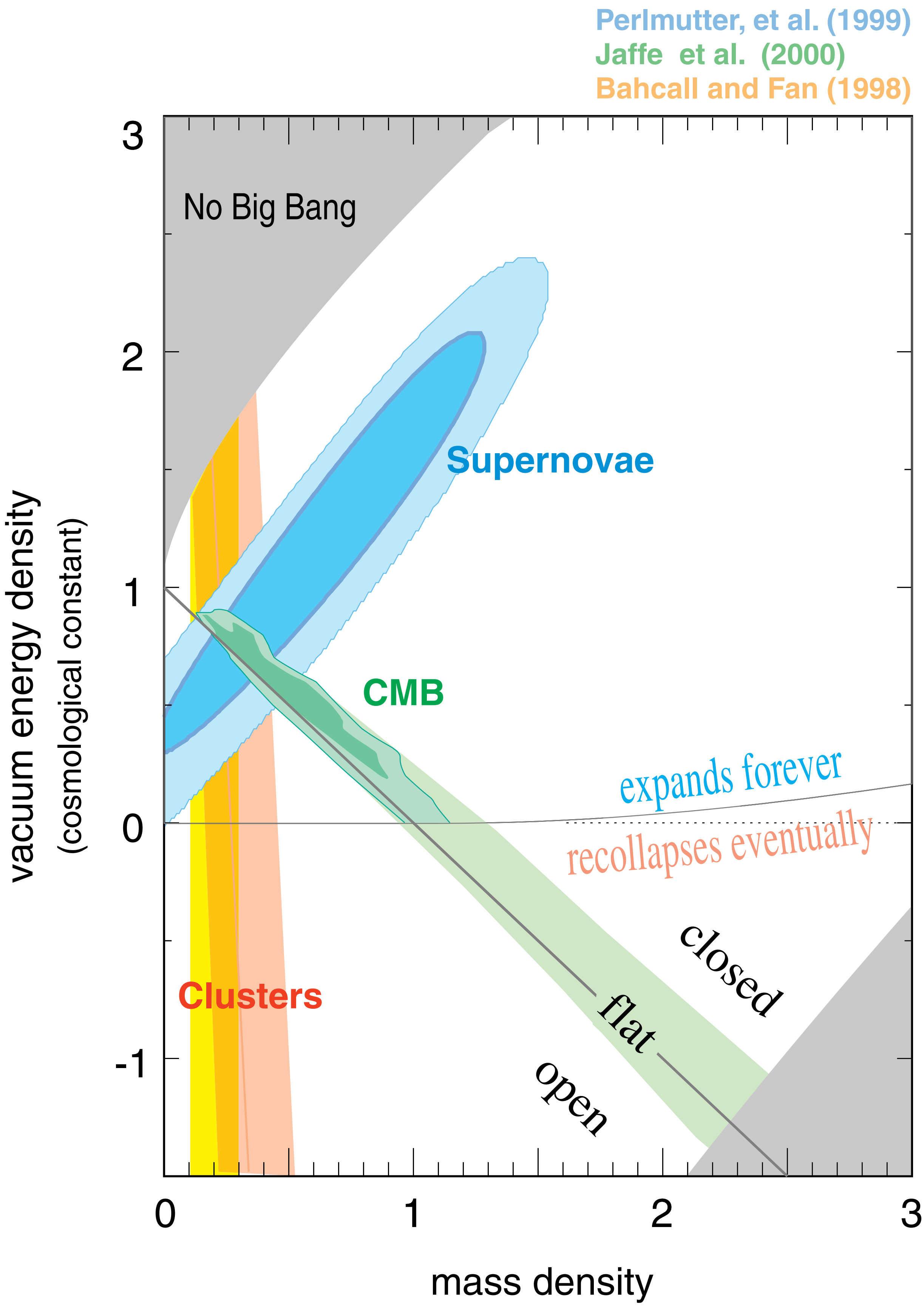
1. How much of mass density and dark energy density is there? I.e., how much dark matter and dark energy do we need to look for?
   The answer to this question determines the "curvature" of the universe, and can tell us about the extent of the universe: infinite or finite.

2. What is the "dark energy"? Particle physics theory proposes a number of alternatives, each with different properties that we can measure. Each of the alternative theories raises some important questions/problems of fundamental physics.

Supernova Cosmology Project
Perlmutter *et al.* (1998)



Two groups results agree:
c.f. Riess *et al.* (1998)



Perlmutter, et al. (1999)
Jaffe et al. (2000)
Bahcall and Fan (1998)
No Big Bang
Supernovae
CMB
expands forever
recollapses eventually
closed
flat
open
Clusters
vacuum energy density
(cosmological constant)
mass density
3
2
1
0
-1
0
1
2
3

What's wrong with a non-zero vacuum energy / cosmological constant?

Two coincidences:

- ***Why so small?***

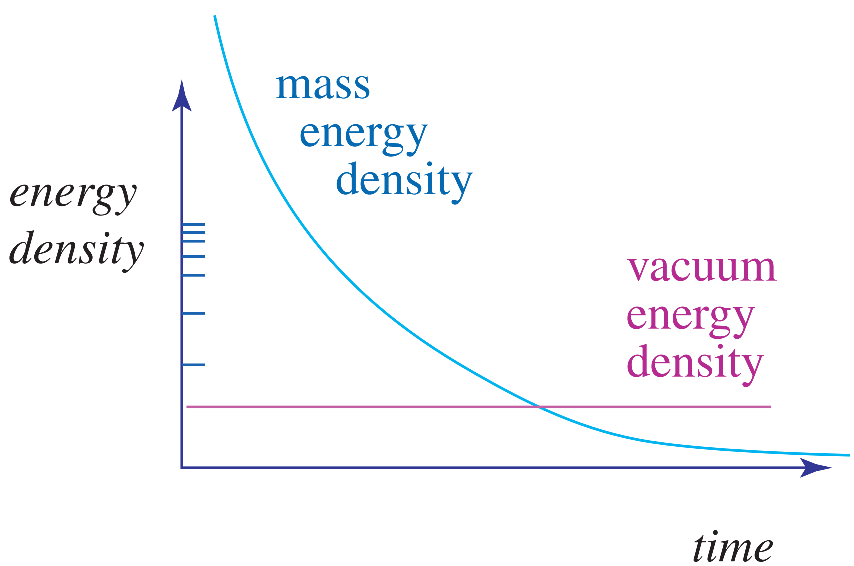
  Might expect $\frac{\Lambda}{8\pi G} \sim m^4_{\mathrm{Planck}}$

  This is off by ~120 orders of magnitude!

- ***"Why now?"***

$$\frac{\ddot{R}}{R} = -\frac{4\pi G}{3}(\rho + 3p)$$

MATTER:	$p = 0$	→	$\rho \propto R^{-3}$
VACUUM ENERGY:	$p = -\rho$	→	$\rho \propto \mathit{constant}$



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MATTER:	$p = 0$	$\longrightarrow \rho \propto R^{-3}$
VACUUM ENERGY:	$p = -\rho$	$\longrightarrow \rho \propto constant$

What are the alternatives?

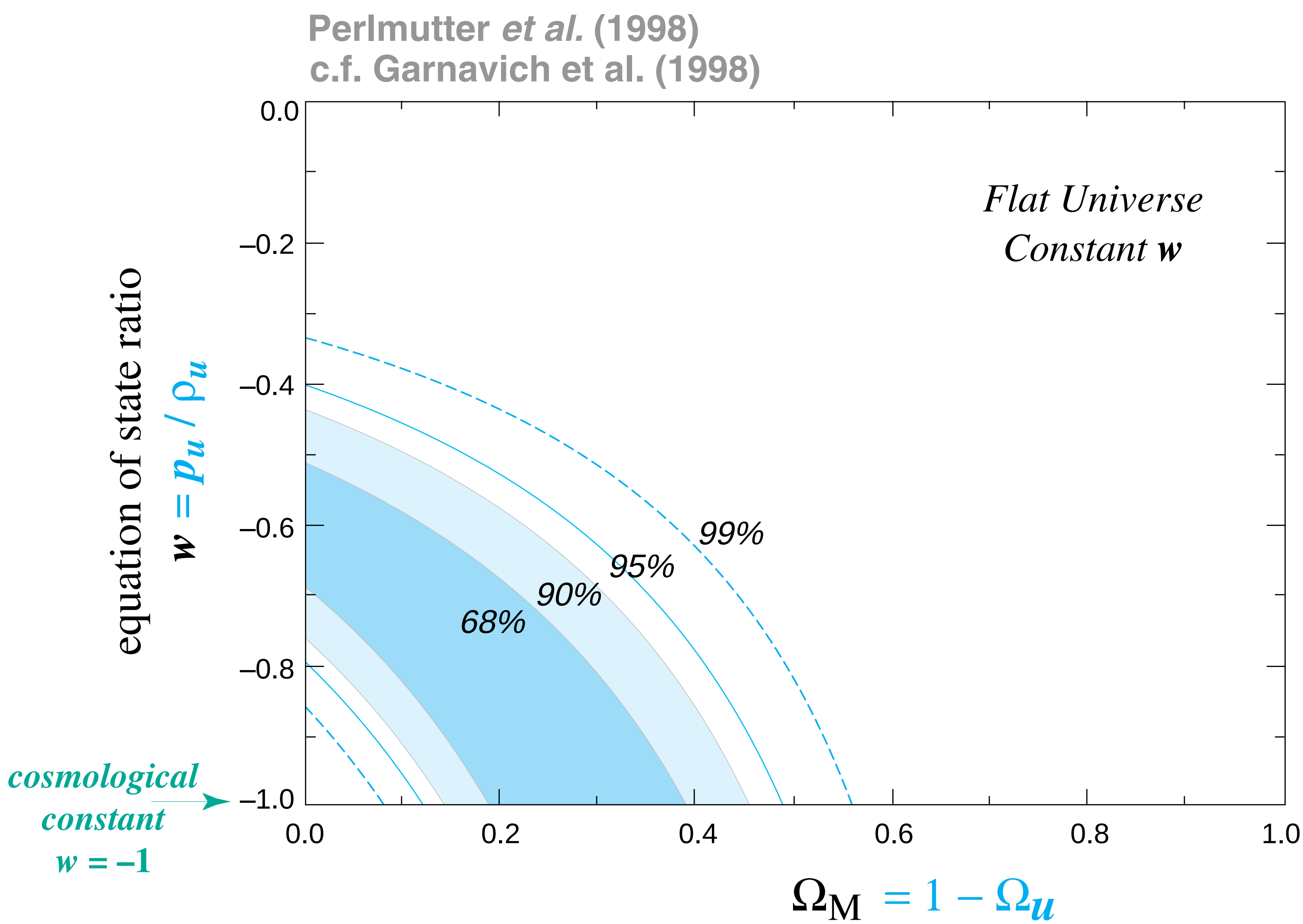
New Physics:

"Dark energy": Dynamical scalar fields, "quintessence",...

COSMIC STRINGS:	$p = -1/3\,\rho$	$\longrightarrow \rho \propto R^{-2}$
General Equation of State:	$p = w\rho$	$\longrightarrow \rho \propto R^{-3(1+w)}$

and w can vary with time

Unknown Component, Ω_u, of Energy Density



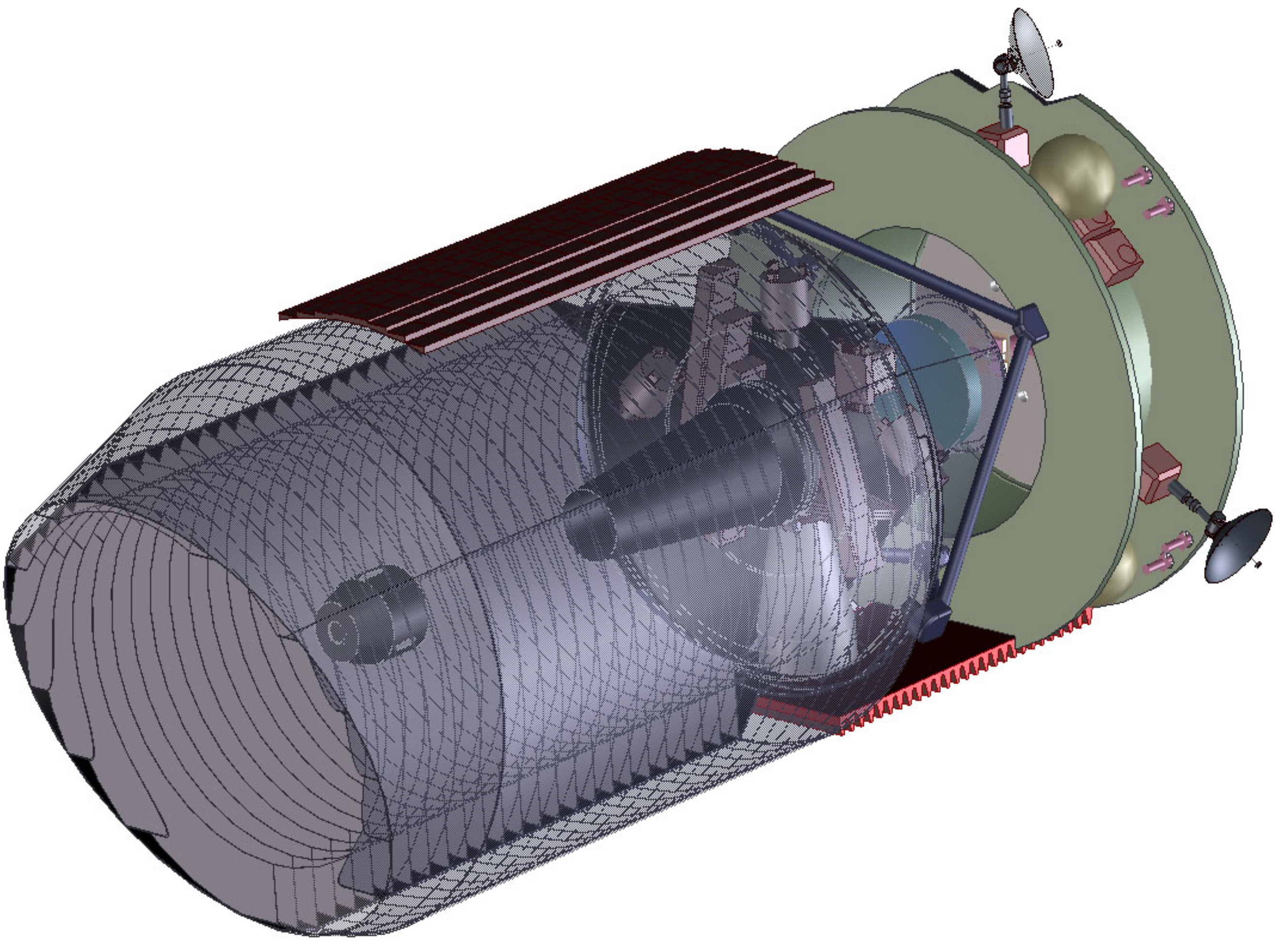
SNAP SuperNova Acceleration Probe

For a definitive measurement
to provide a pillar of our cosmological theory
requires

- a much larger statistical sample of supernovae,
- with much better controlled measurements,
- over a much larger range of redshifts,

that cannot be obtained
with existing or planned facilities.

SNAP SuperNova Acceleration Probe



SNAP SuperNova Acceleration Probe

satellite overview

Instruments:

- **~2 m aperture telescope**
  Can reach very distant SNe.
- **1 square degree mosaic camera, 1 billion pixels**
  Efficiently studies large numbers of SNe.
- **3-arm spectrograph, 0.3um -- 1.7um**
  Detailed analysis of each SN.

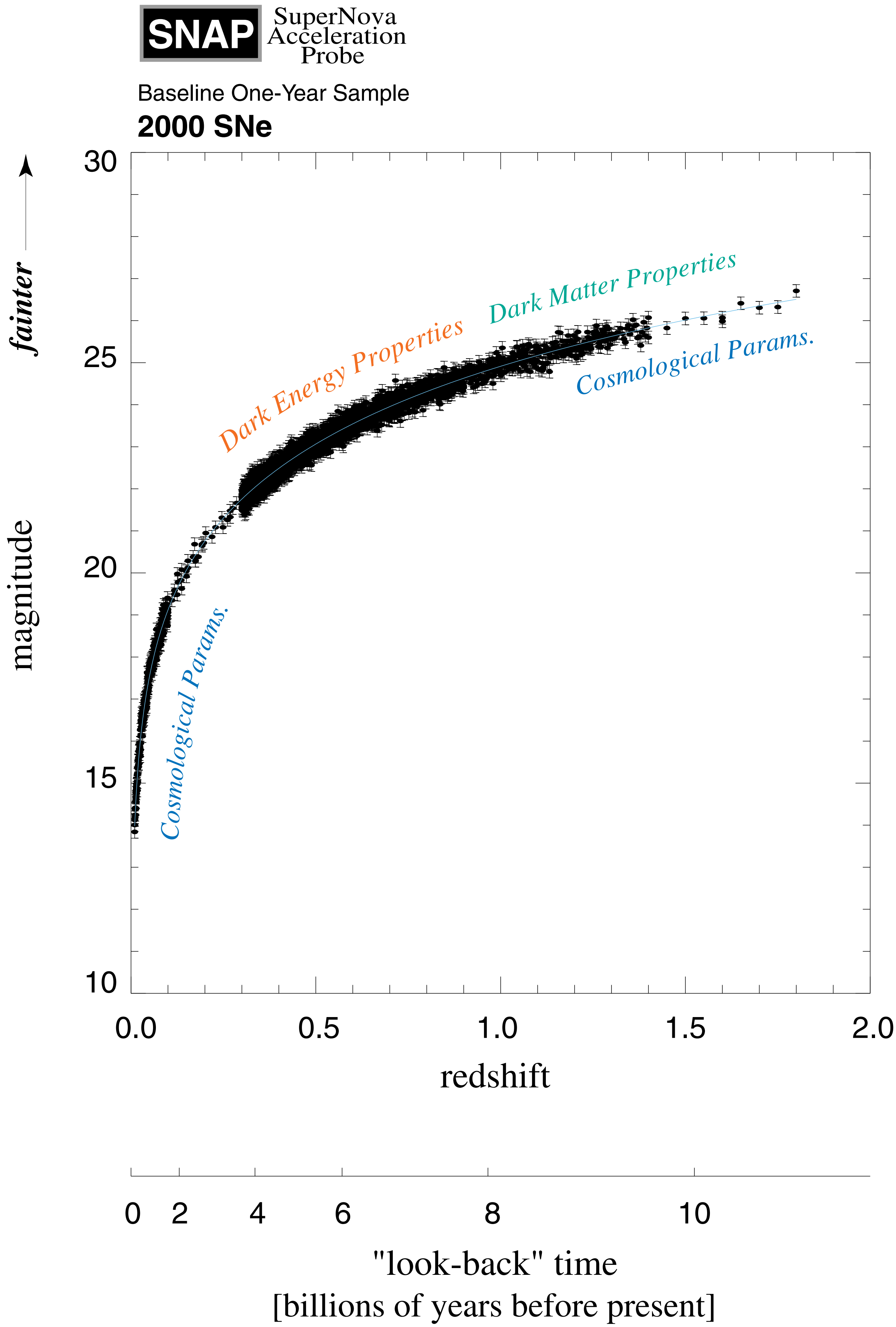
Satellite:

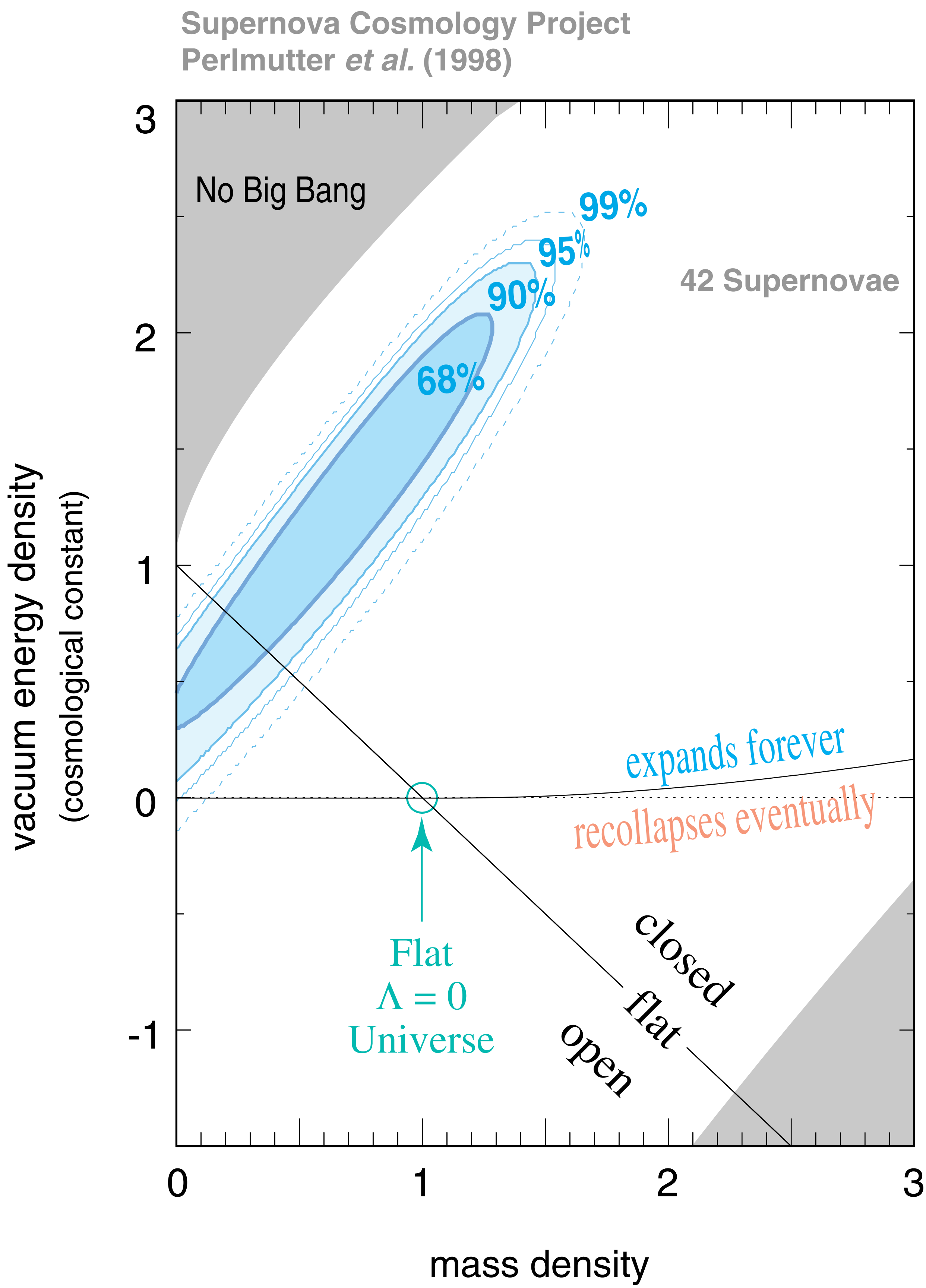
Dedicated instrument.

Designed to repeatedly observe an area of sky.

Essentially no moving parts.

4-year construction cycle.
3-year operation for experiment
(lifetime open-ended).


SNAP
SuperNova Acceleration Probe
Baseline One-Year Sample
2000 SNe
fainter
magnitude
30
25
20
15
10
Dark Energy Properties
Dark Matter Properties
Cosmological Params.
Cosmological Params.
0.0
0.5
1.0
1.5
2.0
redshift
0
2
4
6
8
10
"look-back" time
[billions of years before present]



Supernova Cosmology Project
Perlmutter *et al.* (1998)
No Big Bang
99%
95%
90%
68%
42 Supernovae
expands forever
recollapses eventually
closed
flat
open
Flat
Λ = 0
Universe
vacuum energy density
(cosmological constant)
mass density
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Supernova Cosmology Project
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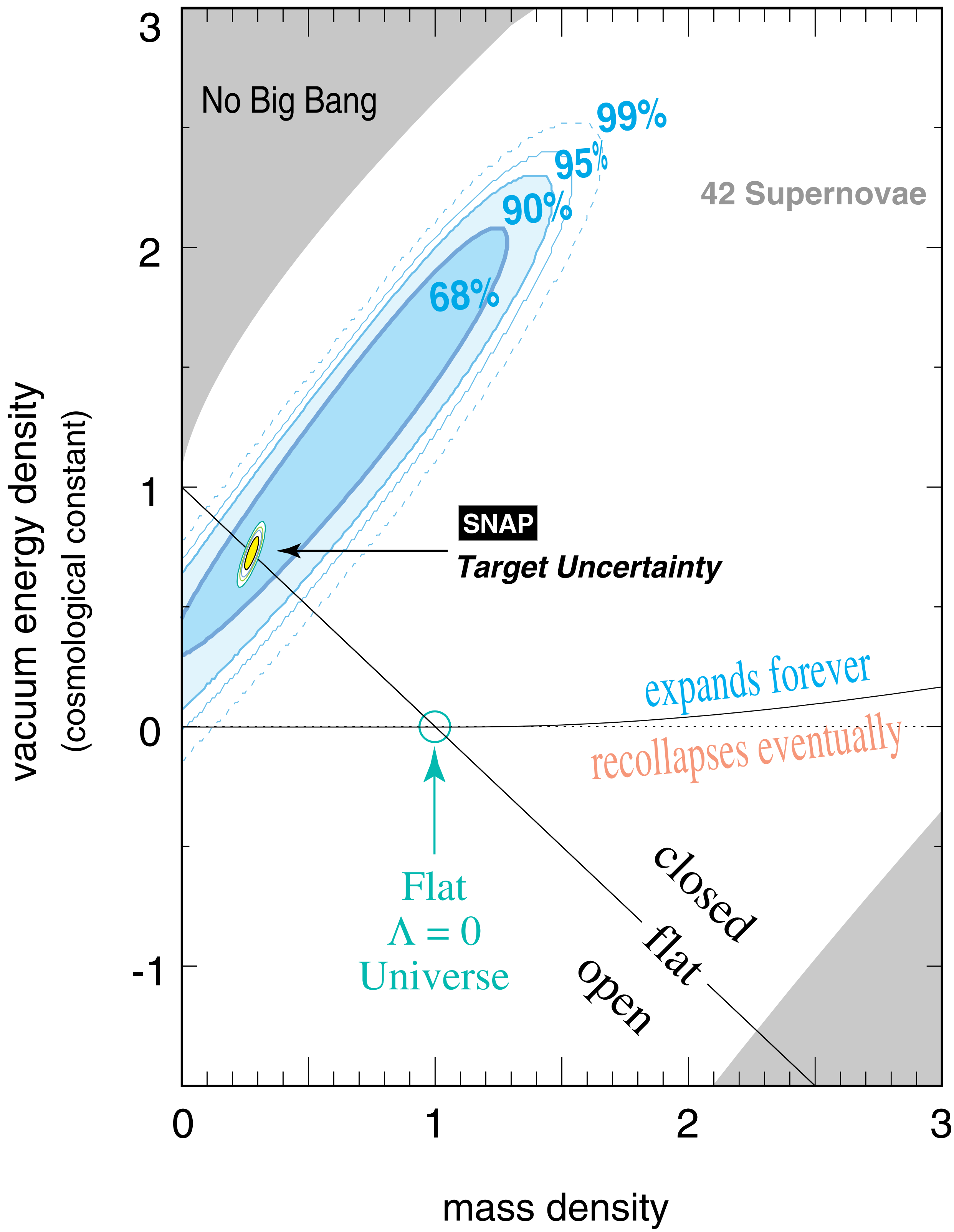

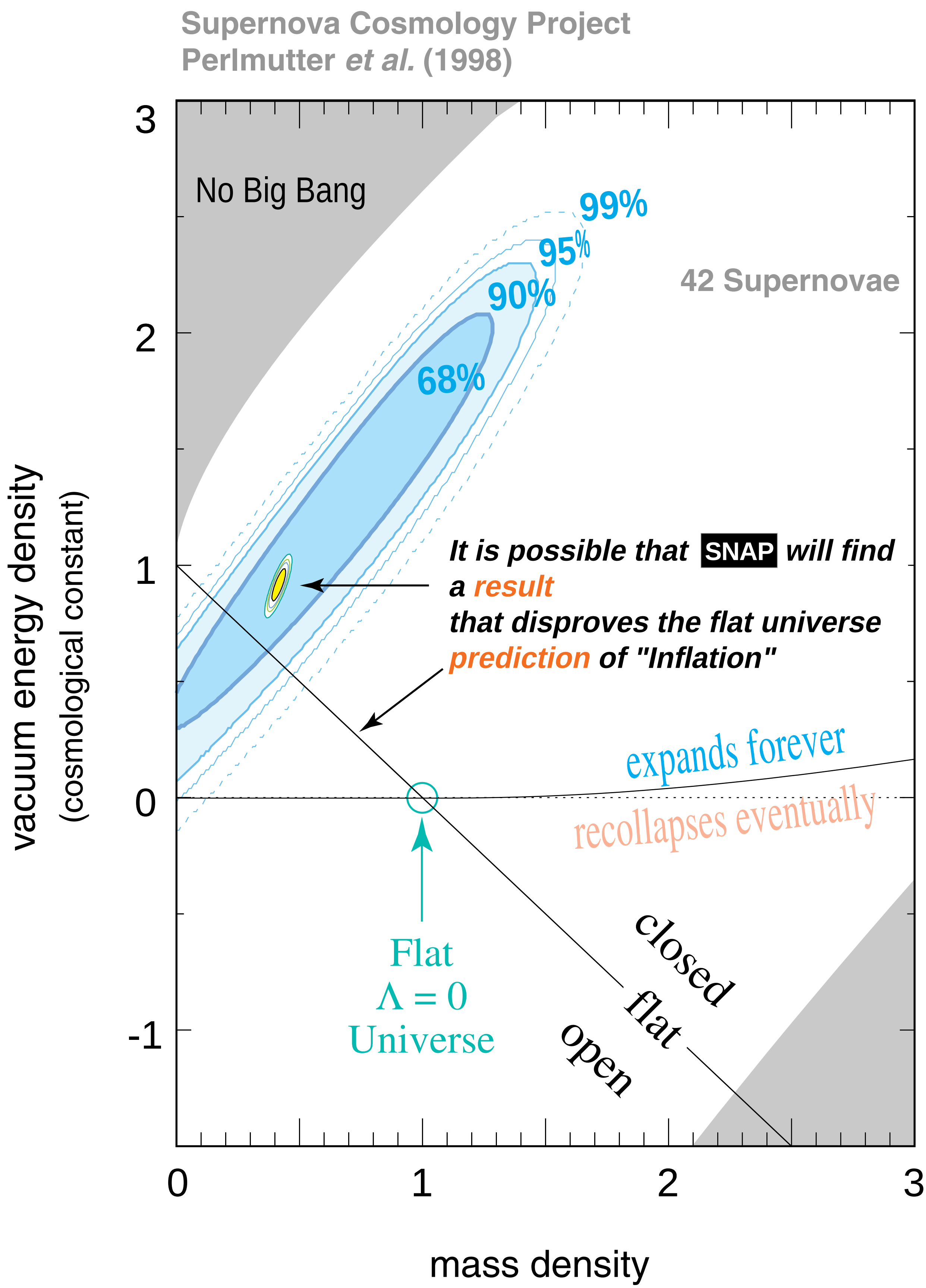
Supernova Cosmology Project
Perlmutter et al. (1998)
No Big Bang
99%
95%
90%
68%
42 Supernovae
It is possible that SNAP will find
a result
that disproves the flat universe
prediction of "Inflation"
expands forever
recollapses eventually
closed
flat
open
Flat
Λ = 0
Universe
vacuum energy density
(cosmological constant)
mass density
3
2
1
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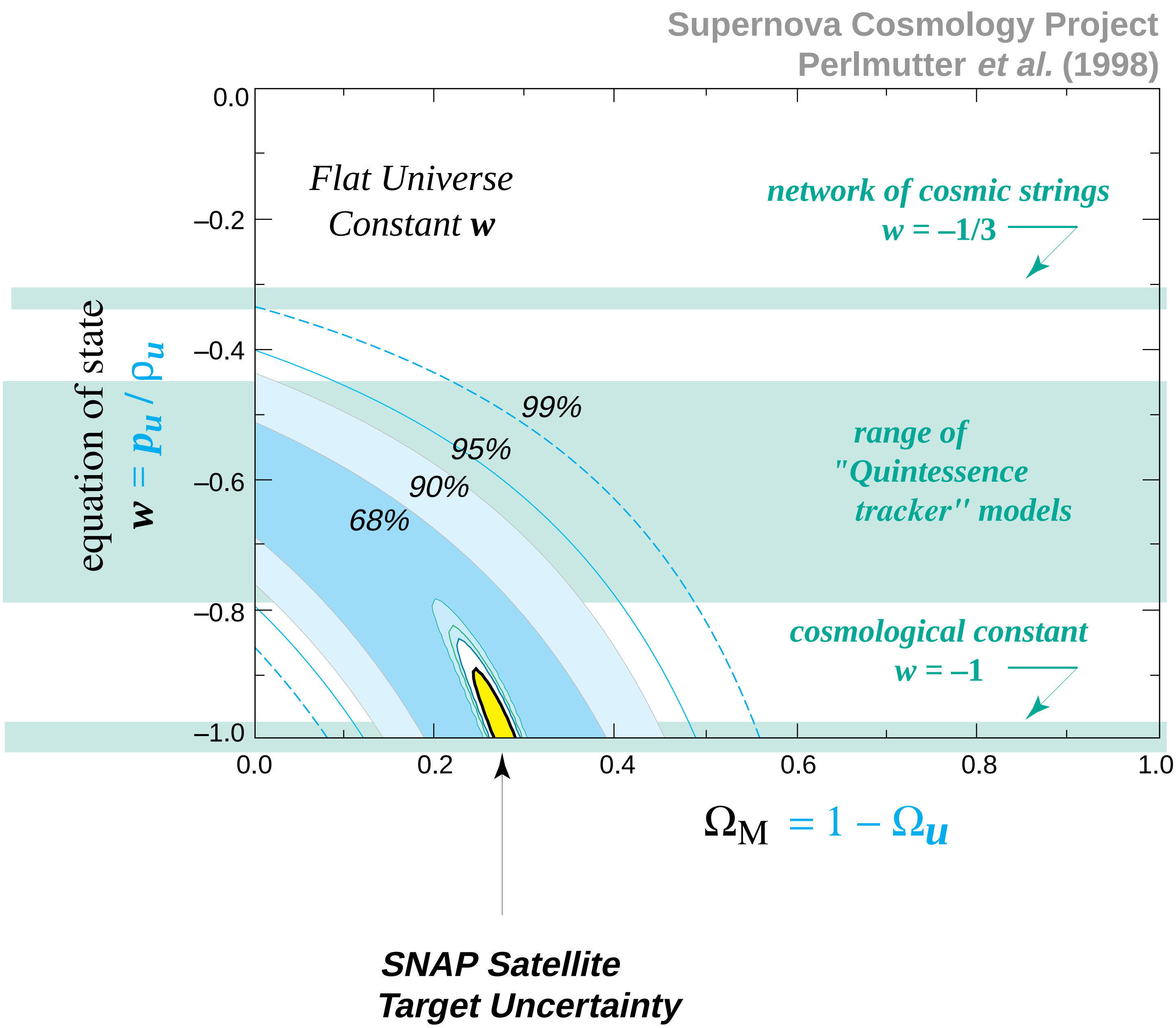
1
2
3

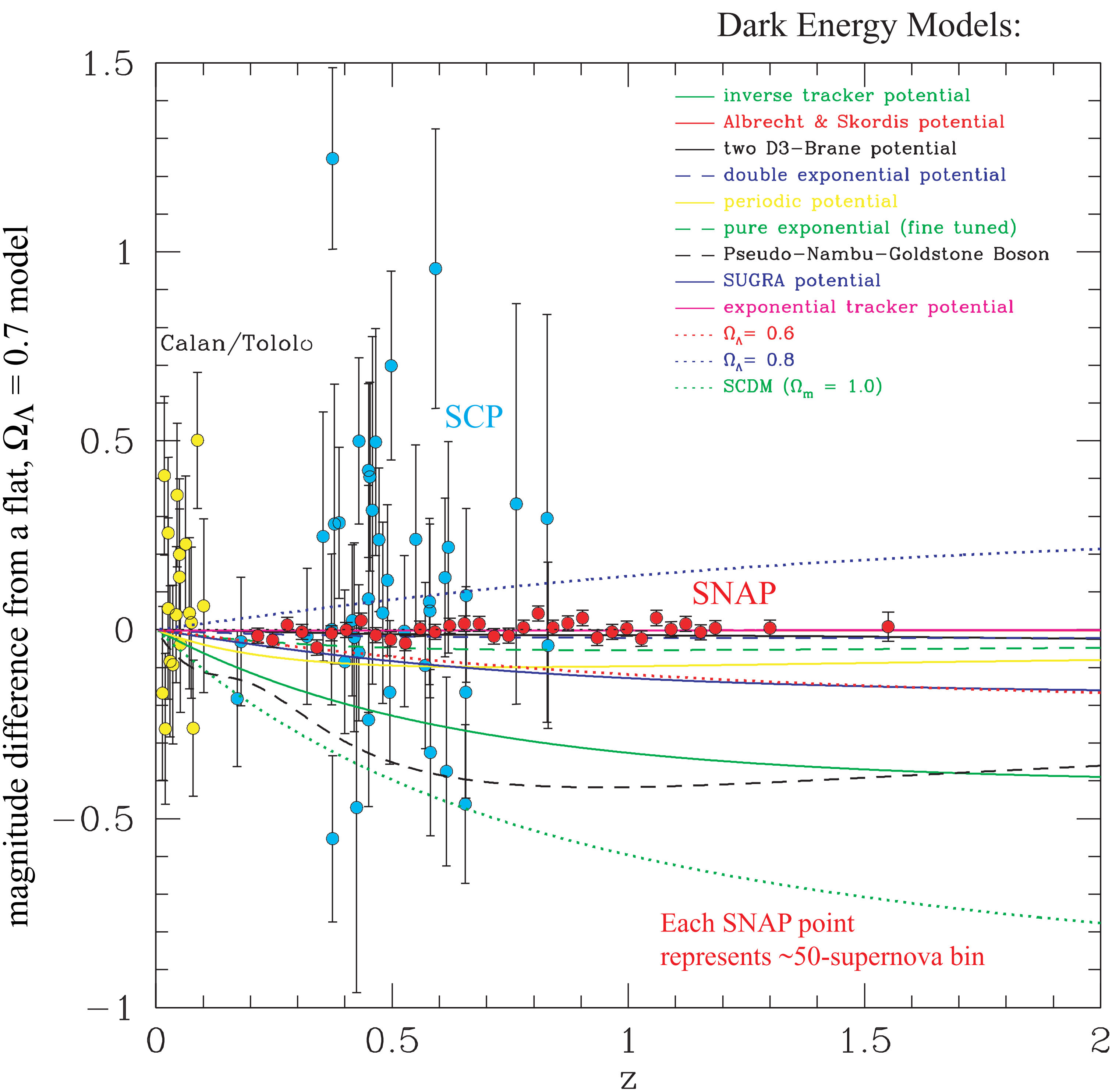
Dark Energy

Unknown Component, Ω_u, of Energy Density



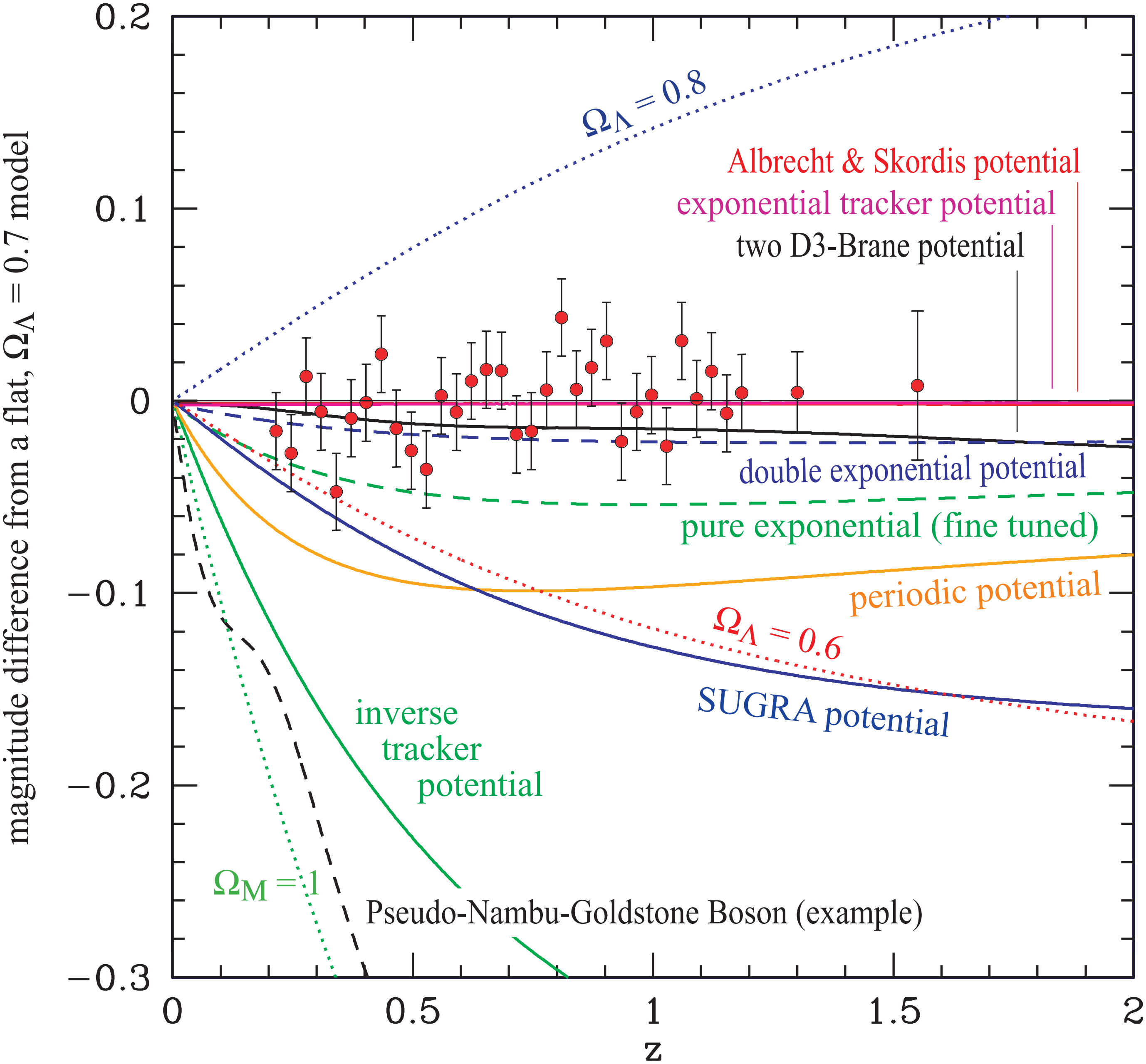
SNAP SuperNova Acceleration Probe

Current ground-based data
compared with binned simulated SNAP data.



SNAP SuperNova Acceleration Probe

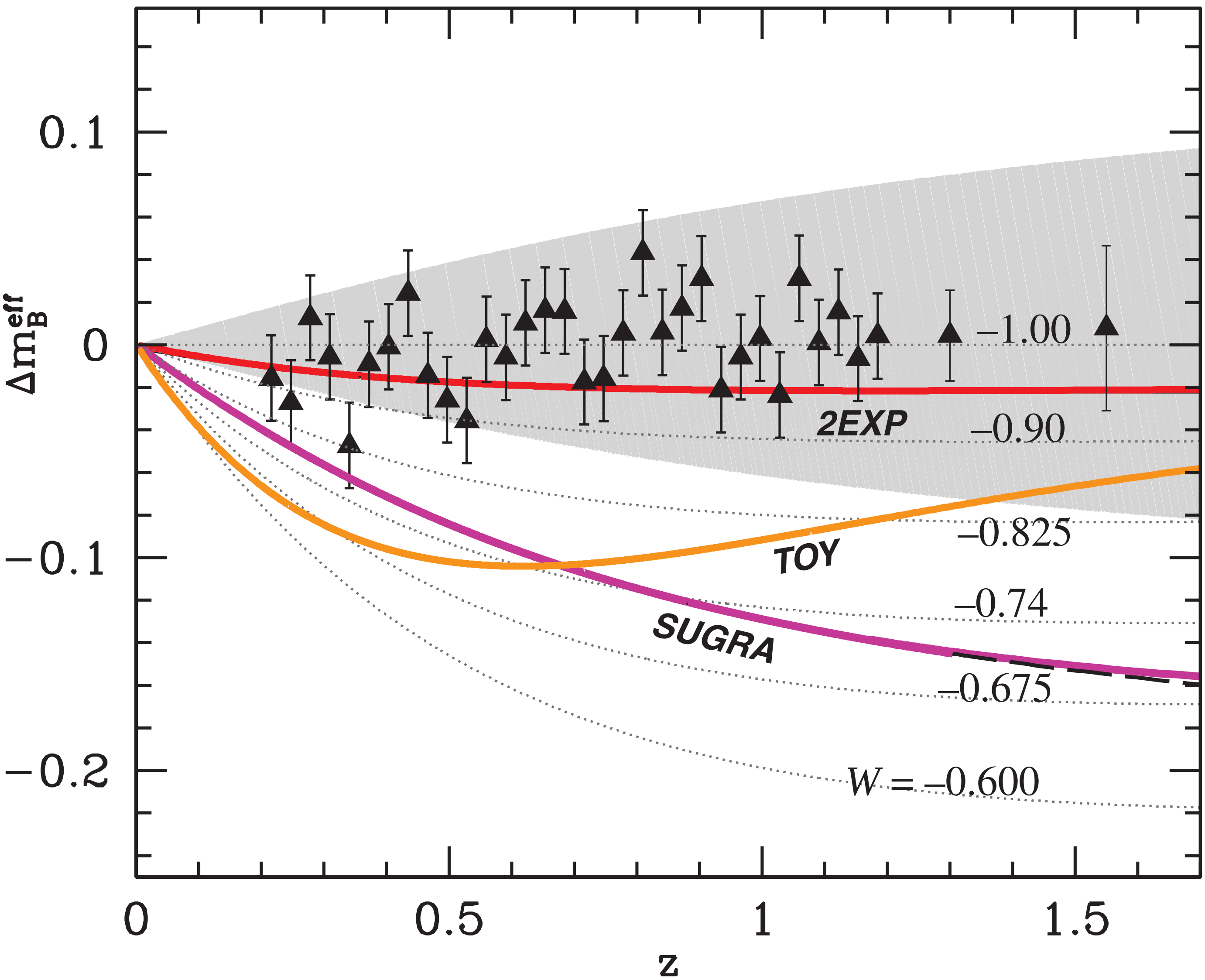
Binned simulated SNAP data compared with Dark Energy models currently in the literature.



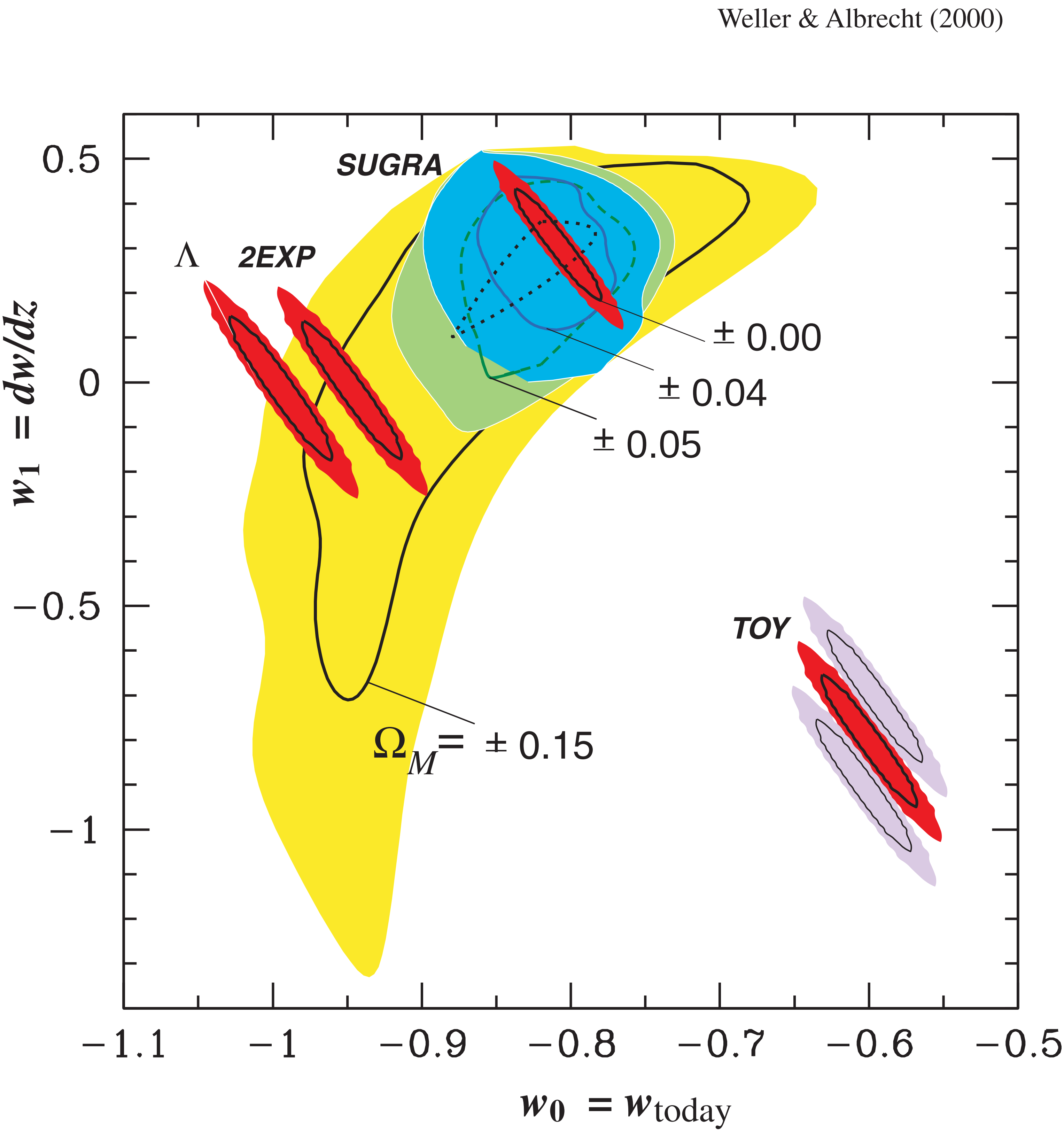
Weller & Albrecht

SNAP SuperNova Acceleration Probe

Binned simulated SNAP data
compared with Dark Energy models.



Weller & Albrecht (2000)



Weller & Albrecht (2000)
SUGRA
Λ
2EXP
TOY
± 0.00
± 0.04
± 0.05
Ω_M = ± 0.15
0.5
0
−0.5
−1
−1.1
−1
−0.9
−0.8
−0.7
−0.6
−0.5
$w_1 = dw/dz$
$w_0 = w_{today}$

SNAP SuperNova Acceleration Probe

science goals

Cosmological Parameters, Dark Matter,...

Type Ia supernova calibrated candle
Type II supernova expanding photosphere
Weak lensing
Strong lensing statistics. Ω_Λ
Galaxy clustering, $P(k)$
$z > 1$ clusters and associated lensing
. . .

...and Beyond

GRB optical counterparts: rates, lightcurves, and spectra
MACHO optical counterparts by proper motion
Galaxy populations and morphology to co-added $m = 32$
Target selection for NGST
Kuiper belt objects
Supernova rates, star formation rates
Supernova phenomenology studies
Low surface brightness galaxies, luminosity function
. . .

→ Archive data distributed:
deeper than Hubble Deep Field
and 7000 times larger

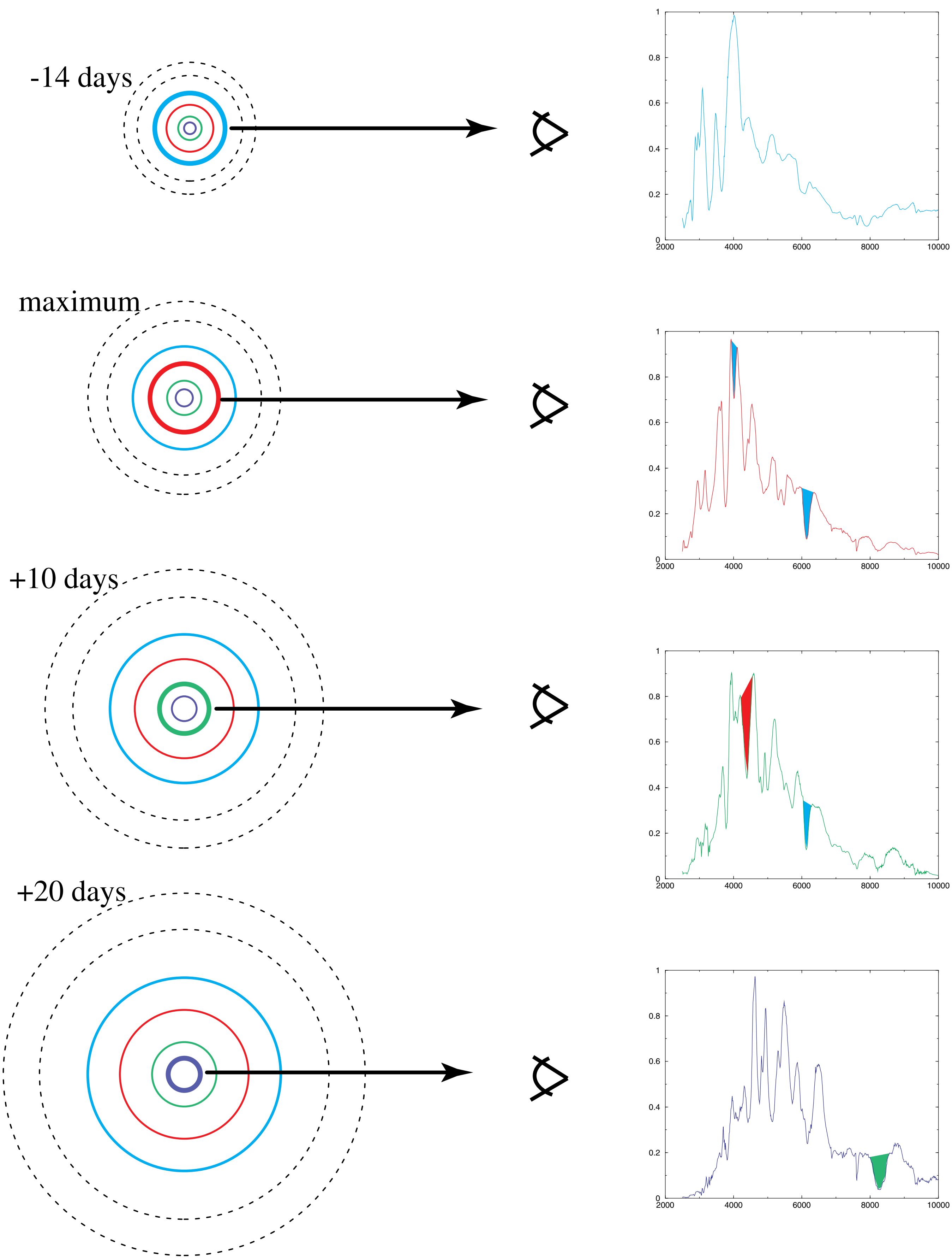
→ Guest Survey Program

SNAP SuperNova Acceleration Probe

What makes the supernova measurement special?
Control of systematic uncertainties.

At every moment in the explosion event,
each individual supernova is "sending" us a rich stream
of information about its internal physical state.

The time series of spectra is a “CAT Scan” of the Supernova



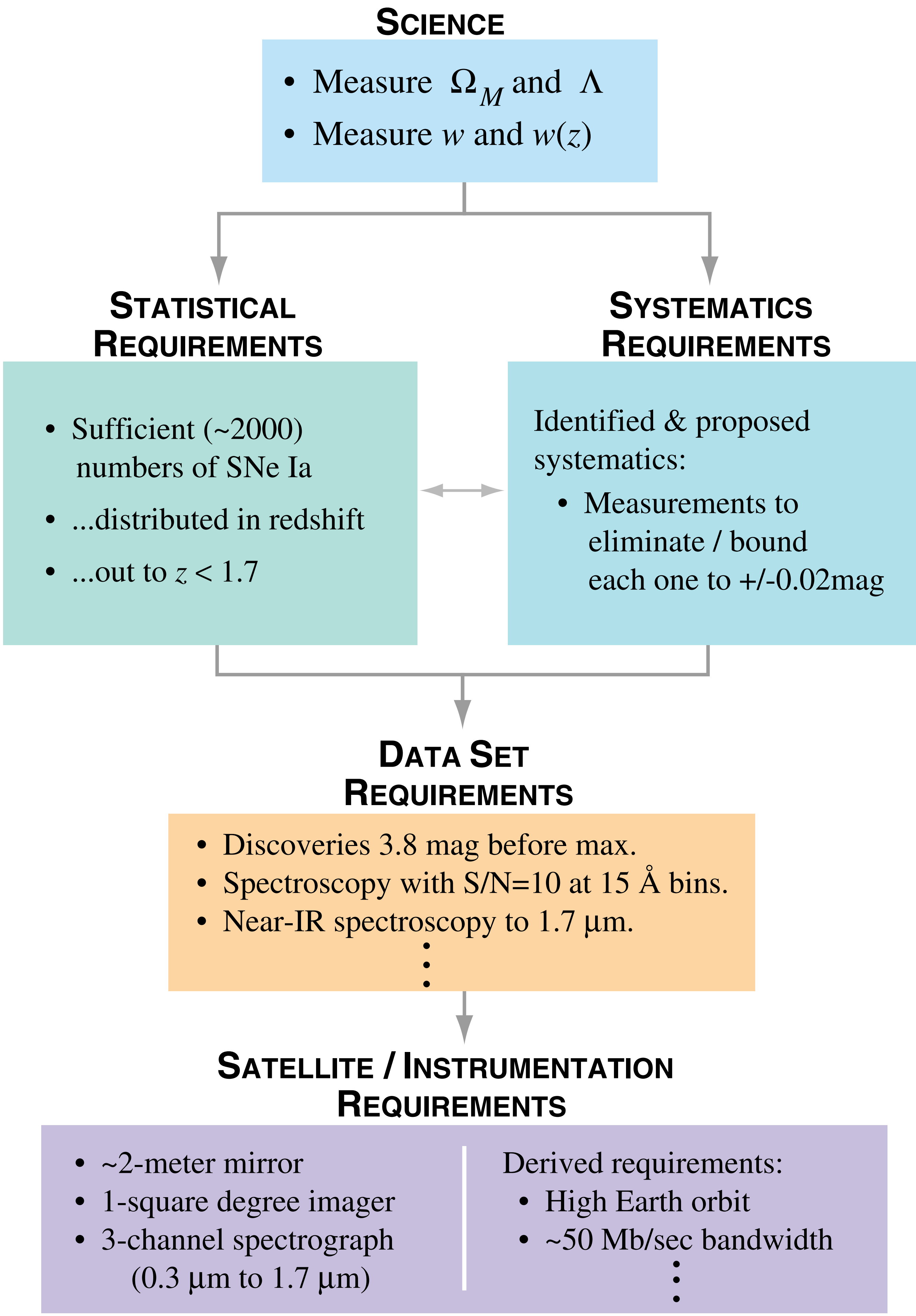
What makes the supernova measurement special?
Control of systematic uncertainties.

However,
for a definitive supernova cosmology measurement...

...it is necessary but NOT sufficient to find and study
- *more SNe Ia*
- *farther SNe Ia*

because the statistical uncertainty is already within a factor of two of the systematic uncertainty.

The most demanding SNAP data requirements are devoted to eliminating and controlling all sytematic uncertainties.



SCIENCE
• Measure Ω_M and Λ
• Measure w and $w(z)$
STATISTICAL REQUIREMENTS
• Sufficient (~2000) numbers of SNe Ia
• ...distributed in redshift
• ...out to $z < 1.7$
SYSTEMATICS REQUIREMENTS
Identified & proposed systematics:
• Measurements to eliminate / bound each one to +/-0.02mag
DATA SET REQUIREMENTS
• Discoveries 3.8 mag before max.
• Spectroscopy with S/N=10 at 15 Å bins.
• Near-IR spectroscopy to 1.7 µm.
SATELLITE / INSTRUMENTATION REQUIREMENTS
• ~2-meter mirror
• 1-square degree imager
• 3-channel spectrograph (0.3 µm to 1.7 µm)
Derived requirements:
• High Earth orbit
• ~50 Mb/sec bandwidth

Score Card of Current Uncertainties

on $(\Omega_{M}^{flat}, \Omega_{\Lambda}^{flat}) = (0.28, 0.72)$

Statistical

☑	high-redshift SNe	0.05
☑	low-redshift SNe	0.065
	Total	***0.085***

Systematic

☑	dust that reddens $R_B(z=0.5) < 2\ R_B(\text{today})$	< 0.03
	evolving grey dust	
?	clumpy	
?	same for each SN	
☑	Malmquist bias difference	< 0.04
?	SN Ia evolution shifting distribution of prog mass/metallicity/C-O/..	
☑	K-correction uncertainty including zero-points	< 0.025
	Total identified entities/processes	***0.05***

Cross-Checks of sensitivity to

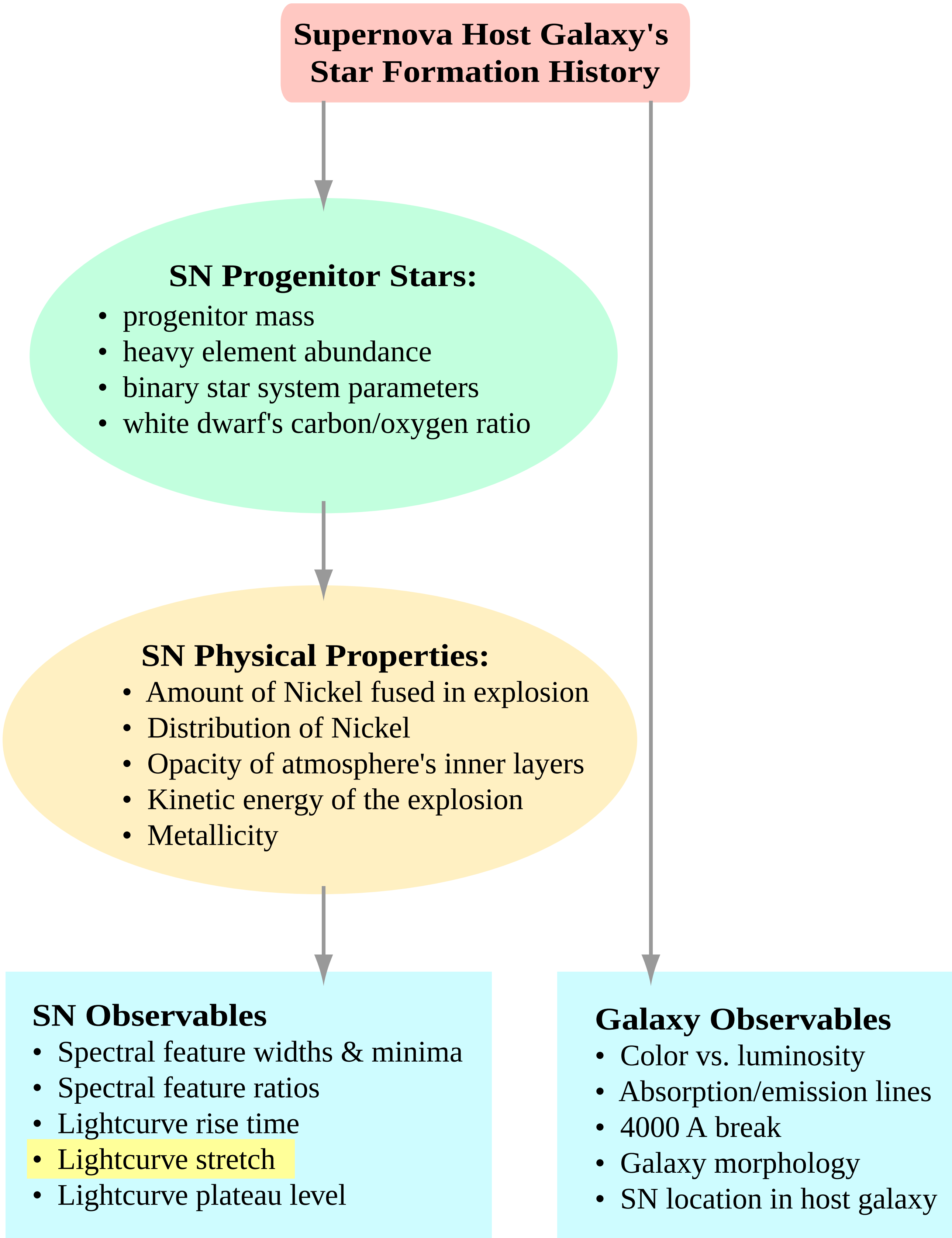
☑	Width-Luminosity Relation	< 0.03
☑	Non-SN Ia contamination	< 0.05
☑	Galactic Extinction Model	< 0.04
☑	Gravitational Lensing by clumped mass	< 0.06

Perlmutter *et al.* (1998)
astro-ph/9812133

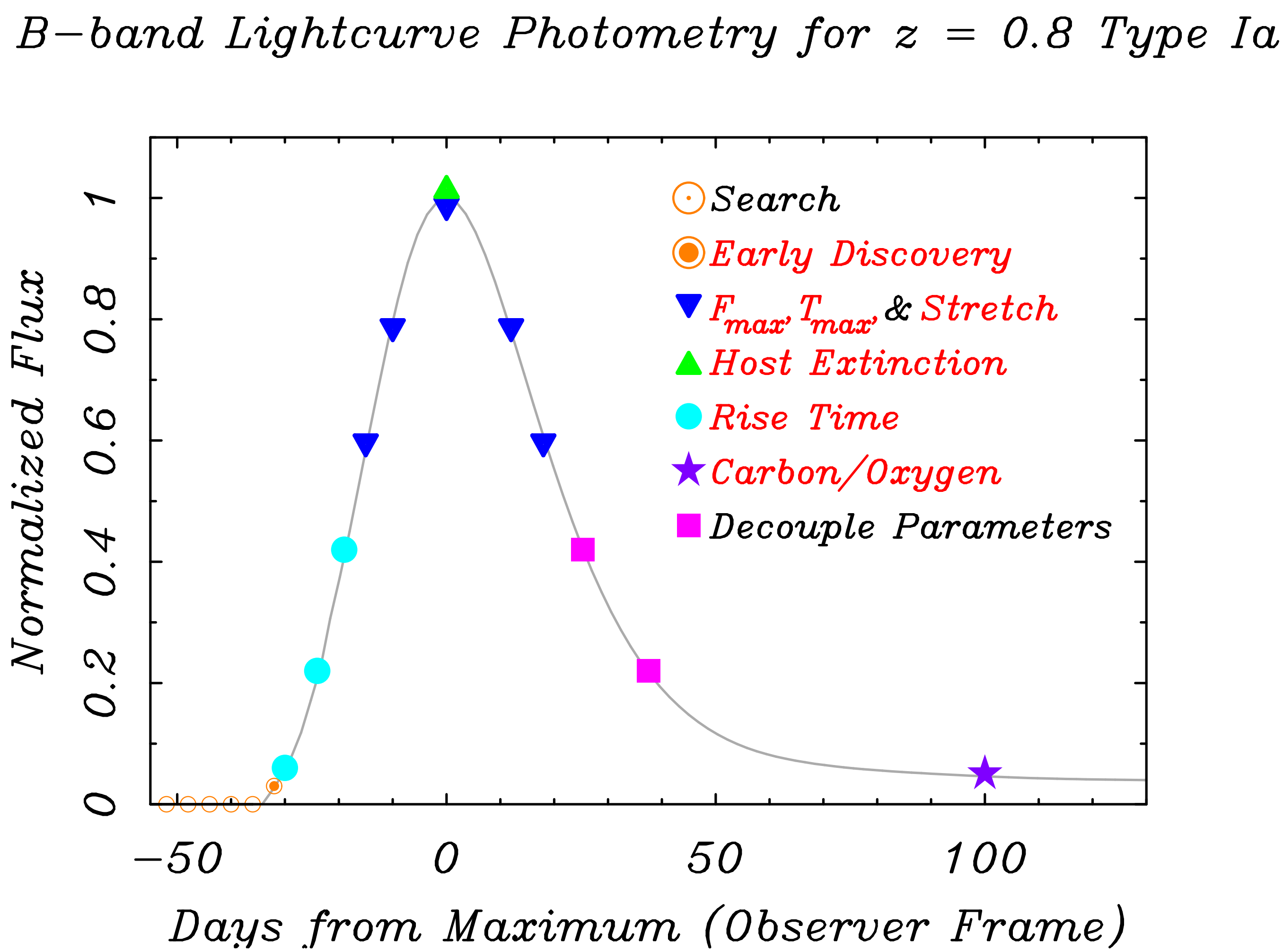
Identified Systematic Uncertainties become Negligible or Statistical Uncertainties

Systematic	Current δM	Requirement to satisfy $\delta M < 0.02$
Malmquist bias	0.04	Detection of every supernova well below peak over entire redshift range
K-Correction and Cross-Filter Calibration	0.03	Spectral time series of representative SN Ia and cross-wavelength relative flux calibration
Non-SN Ia Contamination	< 0.05	Spectrum for every supernova at maximum covering the rest frame Si II 6150Å feature
Milky Way Galaxy extinction	< 0.04	SDSS & SIRTF observations; SNAP spectra of Galactic subdwarfs
Gravitational lensing by clumped mass	< 0.06	Average out the effect with large statistics ($\sim$ 75 SNe Ia per 0.03 redshift bin). SNAP microlensing measurements.
Extinction by "ordinary" dust outside the Milky Way	0.03+	Optical+NIR calibrated spectra to observe wavelength dependent absorption

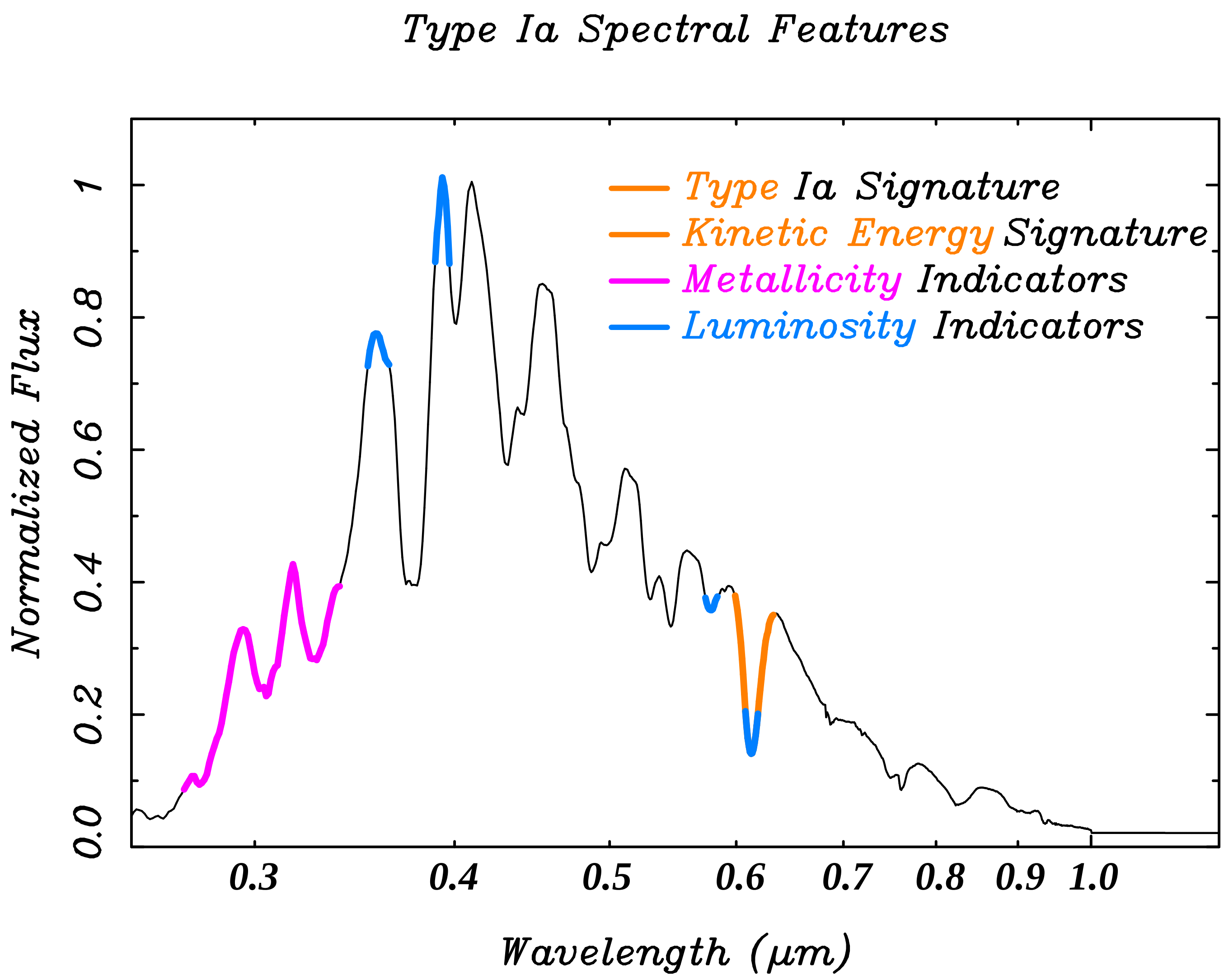
Control of Evolution Systematics: Matching Supernovae



SNAP SuperNova Acceleration Probe



SuperNova Acceleration Probe



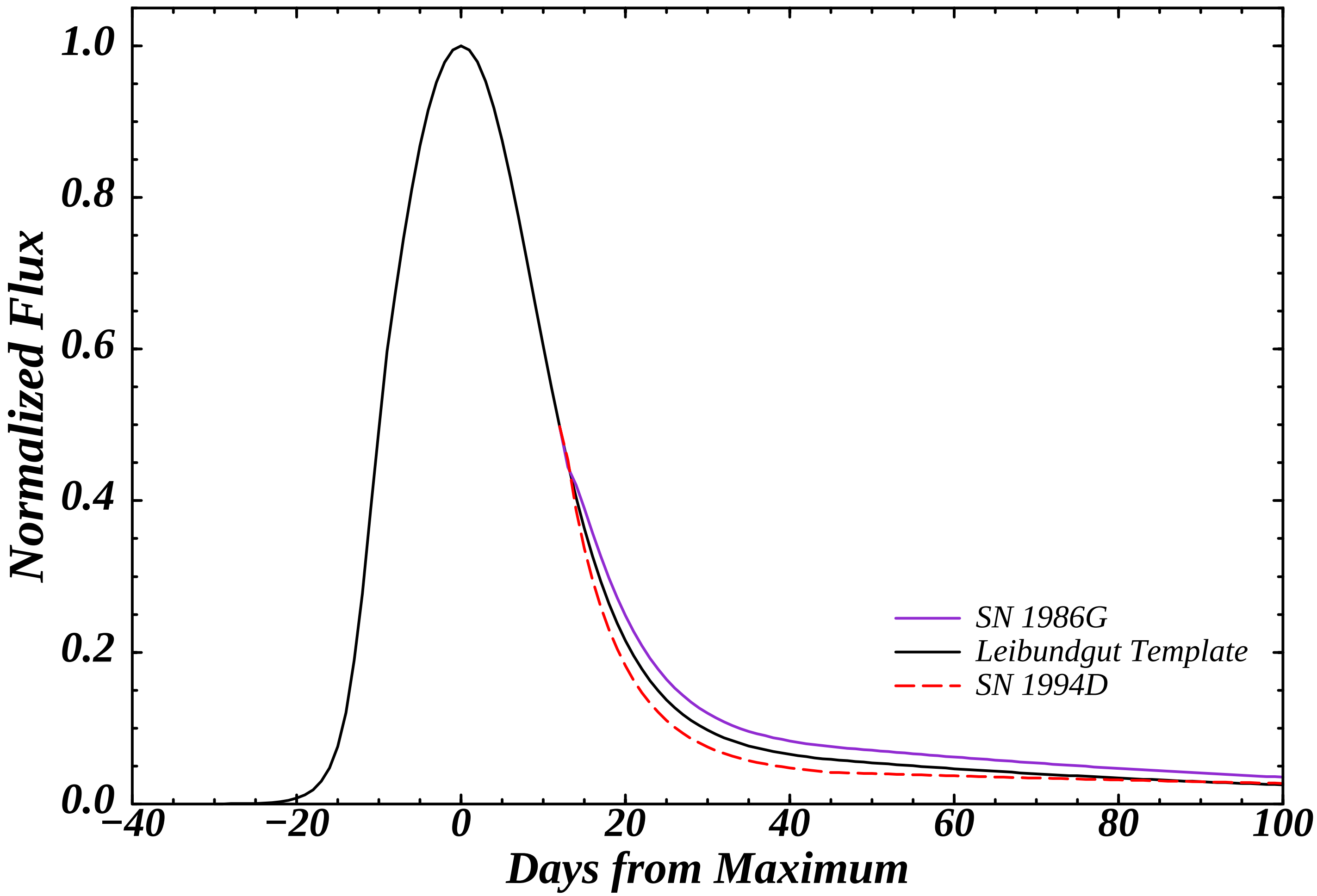
SNAP SuperNova Acceleration Probe

Explosion Parameters from Lightcurve:

Nickel Mass from ***Stretch, Rise−Time***

Nickel Distribution from ***Rise−Time***

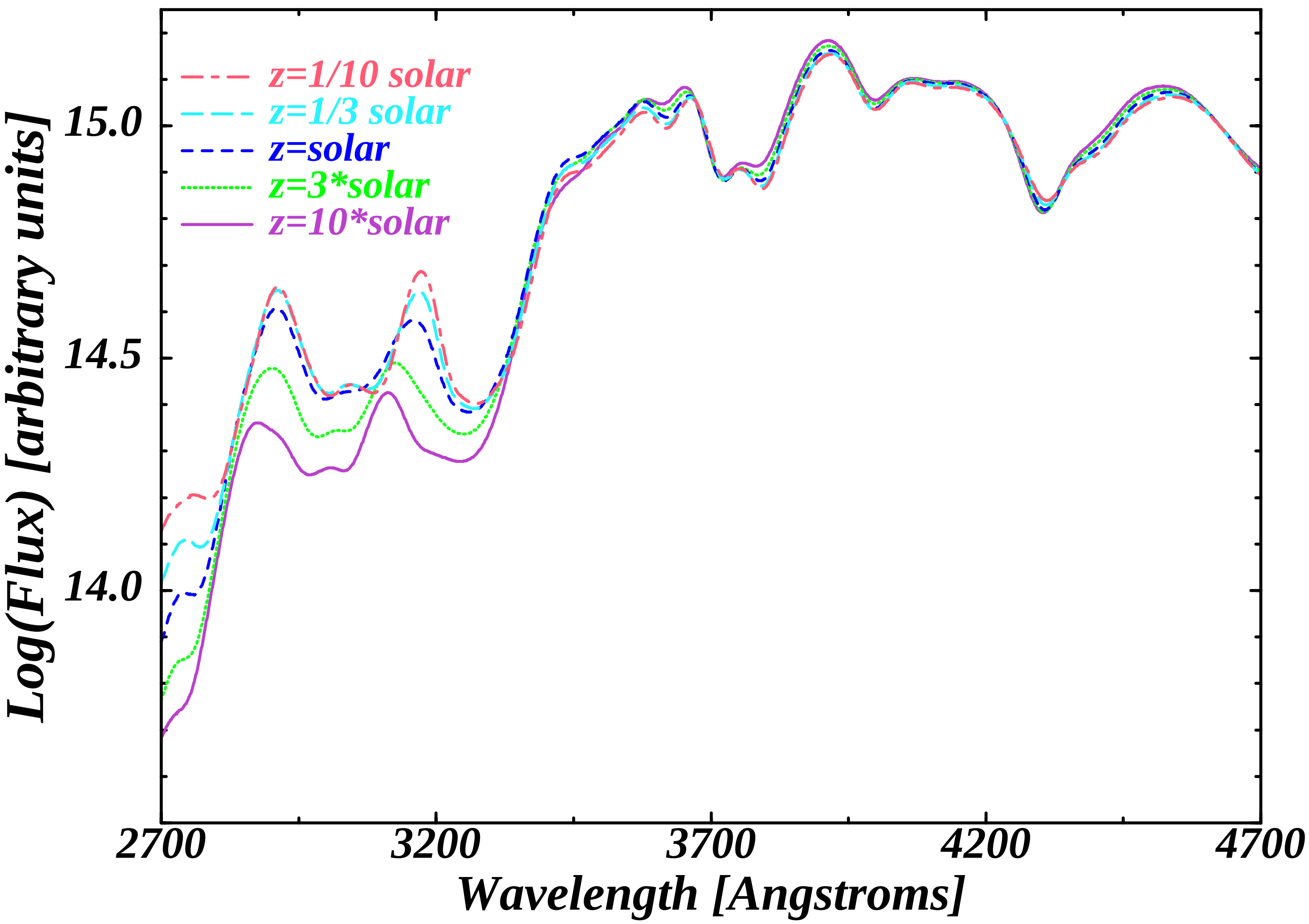
Opacity from ***Stretch, Peak/Tail Ratio***



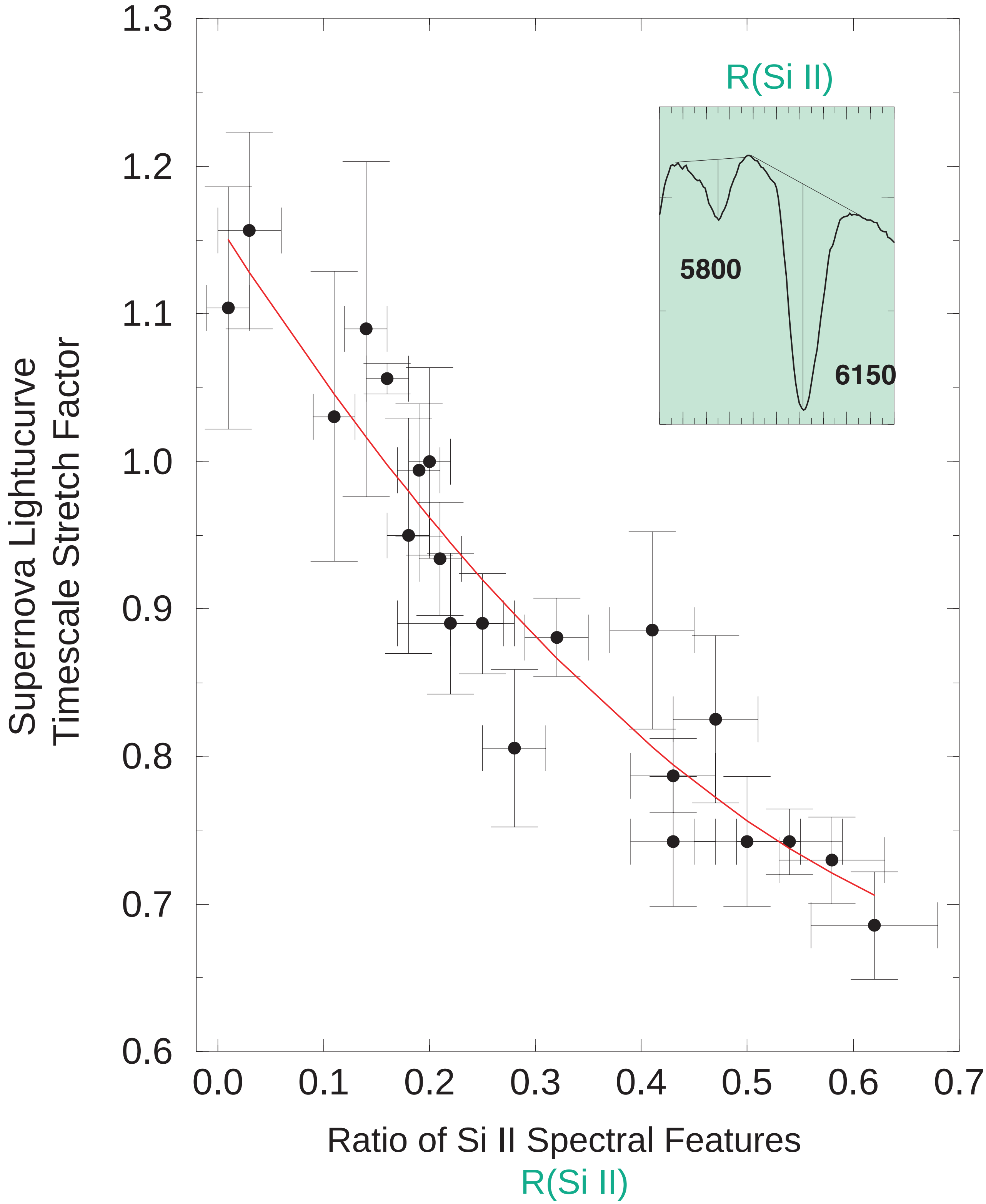
SNAP SuperNova Acceleration Probe

Explosion Parameters from Spectrum:

Kinetic Energy from ***Line Velocities***
Metallicity from ***UV Continuum***
Nickel Mass from ***Line Ratios***



Control of SN Ia Systematics
Using High Signal-to-Noise Spectra

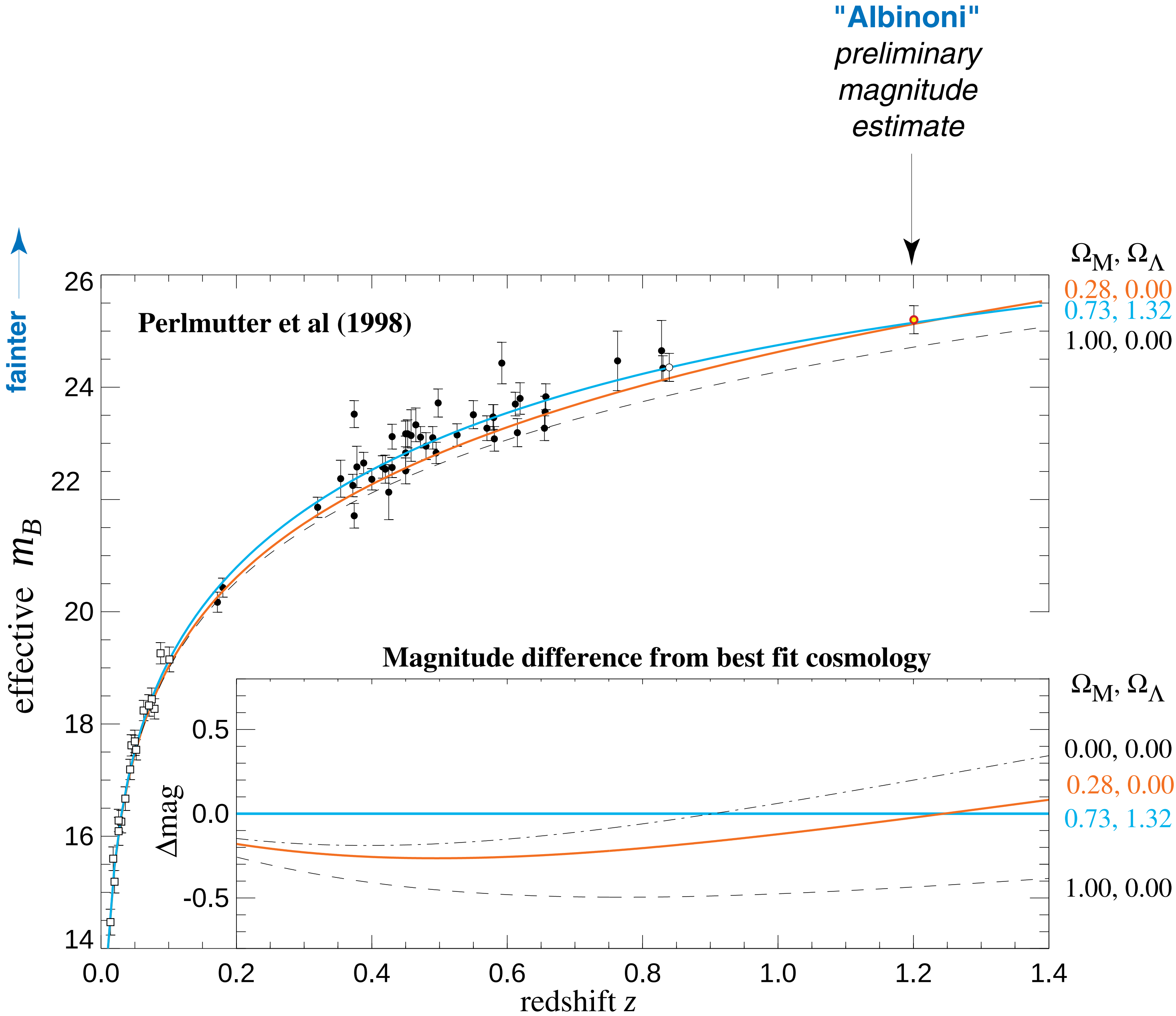


Spectrum & Lightcurve Reveal Explosion Initial Conditions

Observables	^{56}Ni Mass	^{56}Ni Distribution	Kinetic Energy	Opacity	Metal-licity
Spectral feature minima	○	—	●	○	●
Spectral feature widths	○	—	●	○	●
Spectral feature Ratios	●	—	○	○	●
Lightcurve Stretch	●	○	○	●	—
Lightcurve Rise Time	●	●	○	○	○
Lightcurve Peak/Tail	○	—	○	●	—

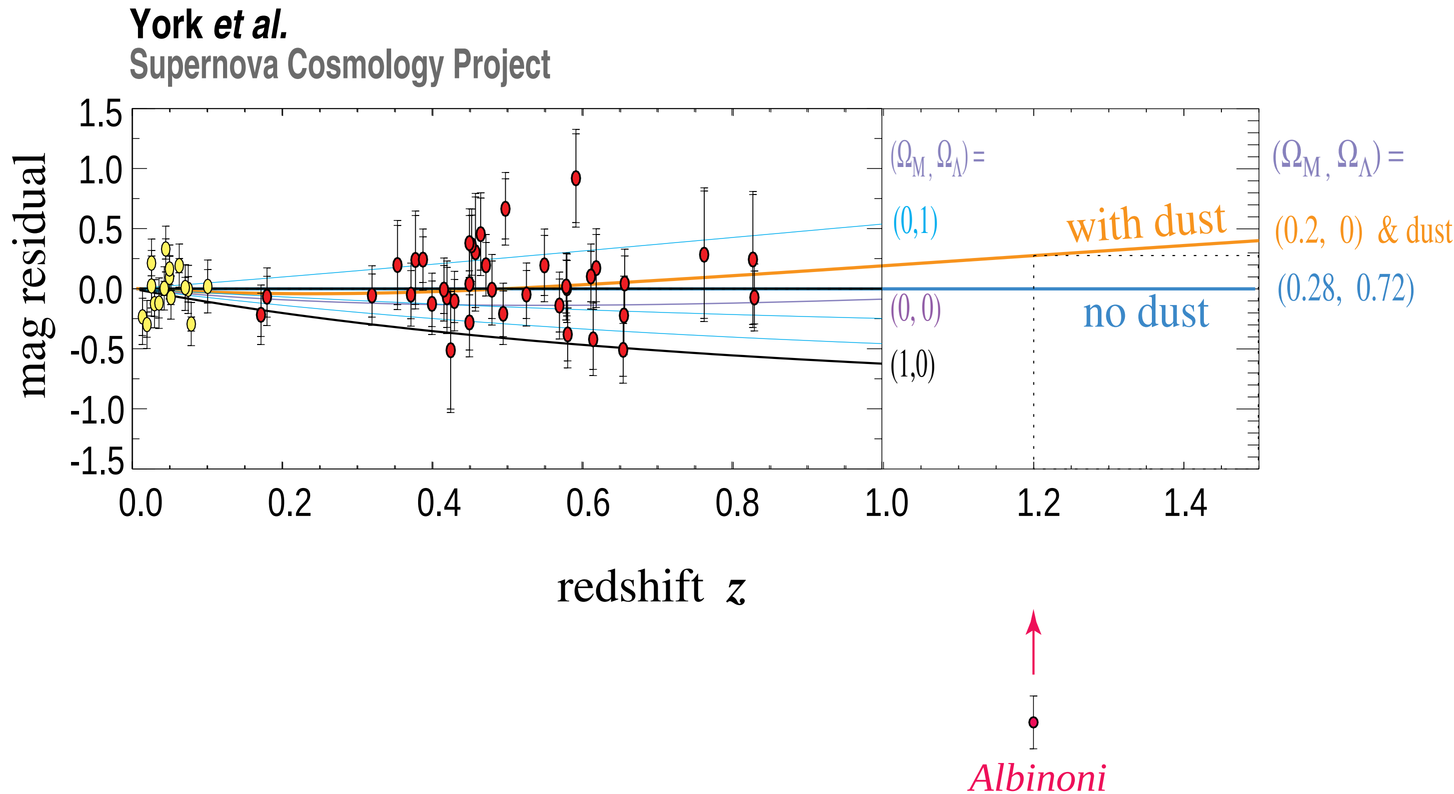
● = directly related to model parameter
○ = indirectly related to model parameter
— = slightly related to or no relation to the model parameter

SNAP will measure all of these Observables



"Albinoni"
preliminary
magnitude
estimate
fainter
Perlmutter et al (1998)
effective m_B
Ω_M, Ω_Λ
0.28, 0.00
0.73, 1.32
1.00, 0.00
26
24
22
20
18
16
14
Magnitude difference from best fit cosmology
Ω_M, Ω_Λ
0.00, 0.00
0.28, 0.00
0.73, 1.32
1.00, 0.00
Δmag
0.5
0.0
-0.5
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
redshift z

Recognizing
Intergalactic Grey Dust
Using SNe at Redshifts > 1



see Aguirre (1999)
astro-ph/9904319

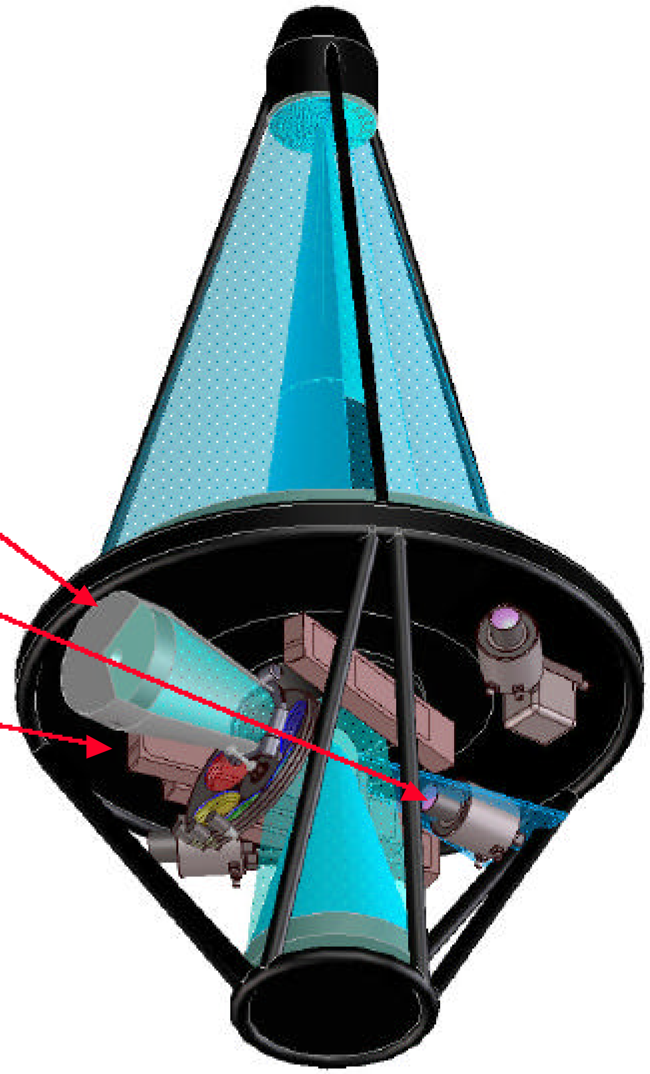
SNAP Instrumentation Suite

Key Instruments:

1) GigaCAM
   - 1 sq. deg FOV
   - 128 3kx3k CCD's

2) IR Photometer
   - (small field of view)

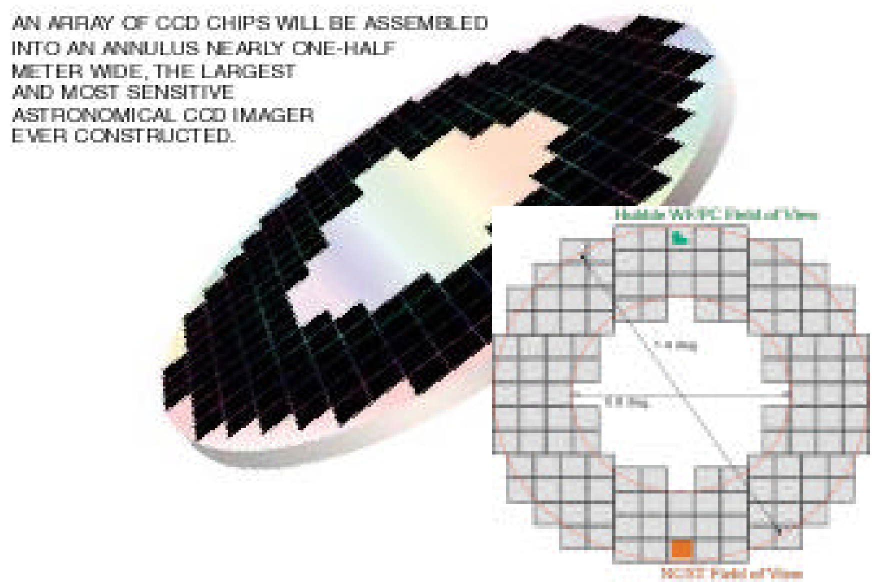
3) 3-channel spectrograph
   - 350-600 nm,
   - 550-1000 nm,
   - 900-1700 nm



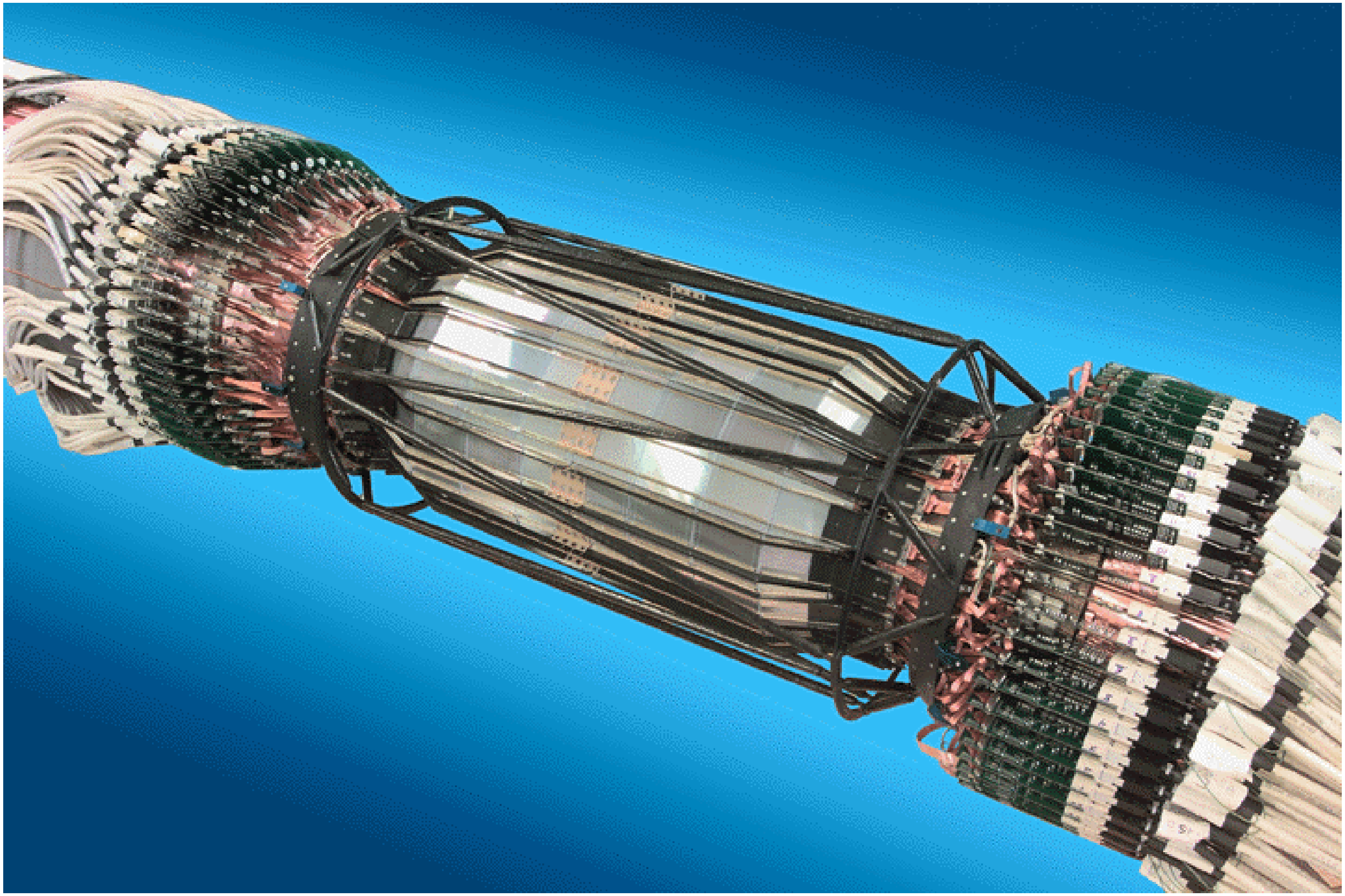
GigaCAM

GigaCAM, a one billion pixel array

- Depending on pixel scale approximately 1 billion pixels
- ~128 Large format CCD detectors required
- Looks like the SLD vertex detector in Si area (0.1 - 0.2 m^2)
- Larger than SDSS camera, smaller than BaBar Vertex Detector (1 m^2)
- Collaboration has lots of experience in building very large silicon detectors and custom readout electronics including radiation hard integrated circuits (should they be necessary).



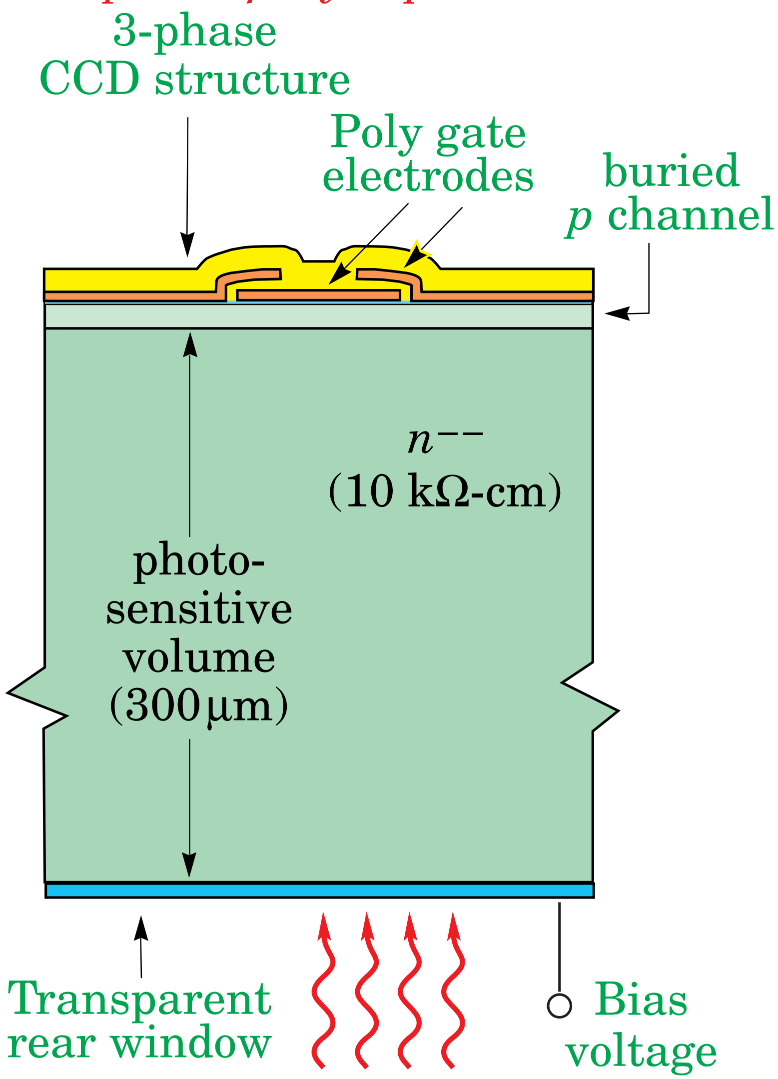
BaBAR Silicon Vertex Detector (~1m² Si)



Fully-Depleted CCD's

The New Approach:

Make a thick CCD on a high-resistivity n-type substrate, to operate fully depleted with rear illumination.



Advantages:

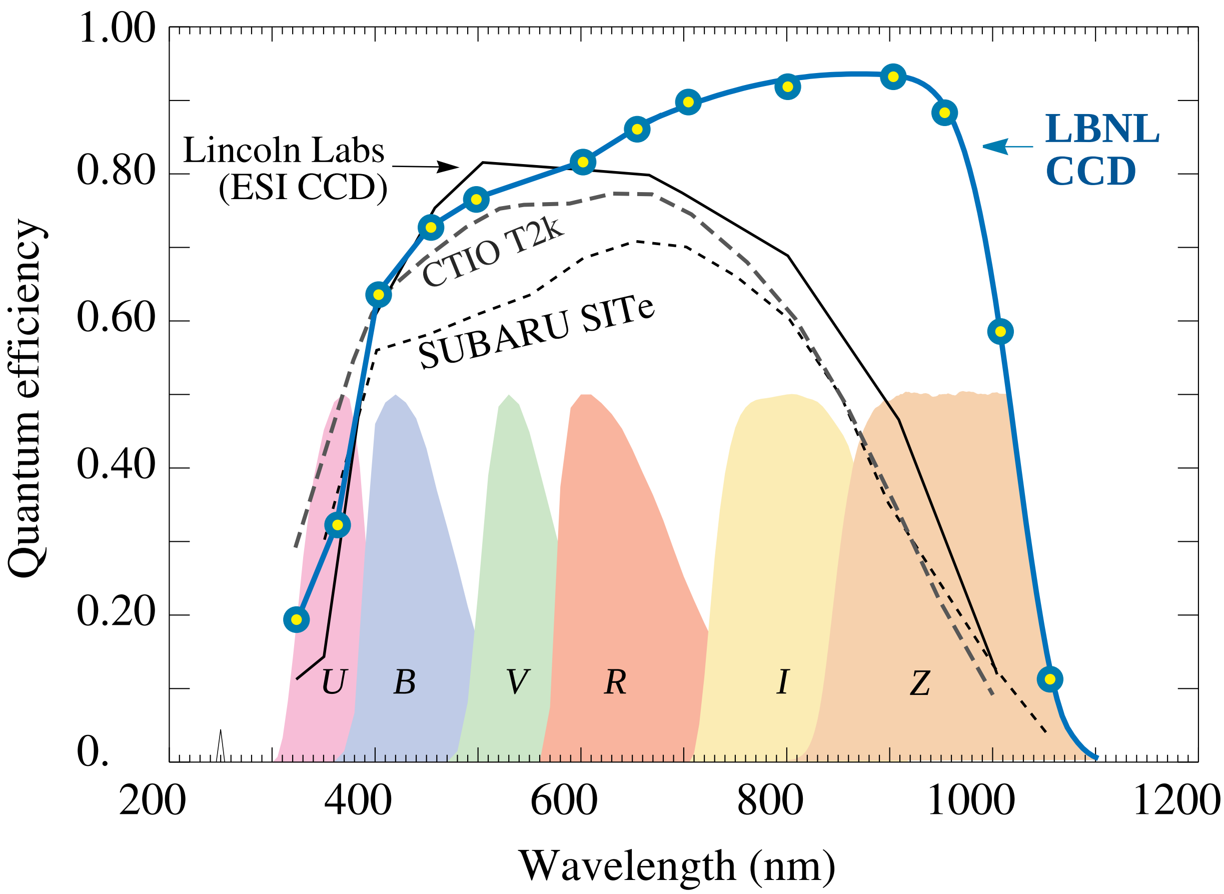
1) Conventional MOS processes with no thinning => "inexpensive"
2) Full quantum efficiency to > 1 µm => no fringing
3) Good blue response with suitably designed rear contact
4) Radiation tolerant

Disadvantages:

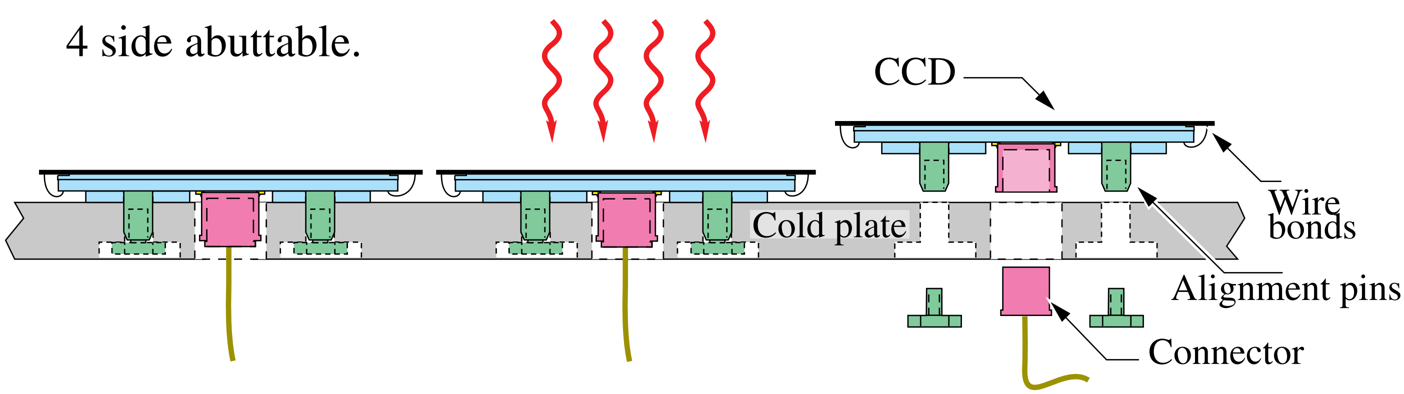
1) Enhanced sensitivity to radiation (x-rays, cosmic rays, radioactive decay)

LBNL CCD Technology

High quantum efficiency from near UV to near IR
No thinning, no fringing.
High yield.
Radiation hard.

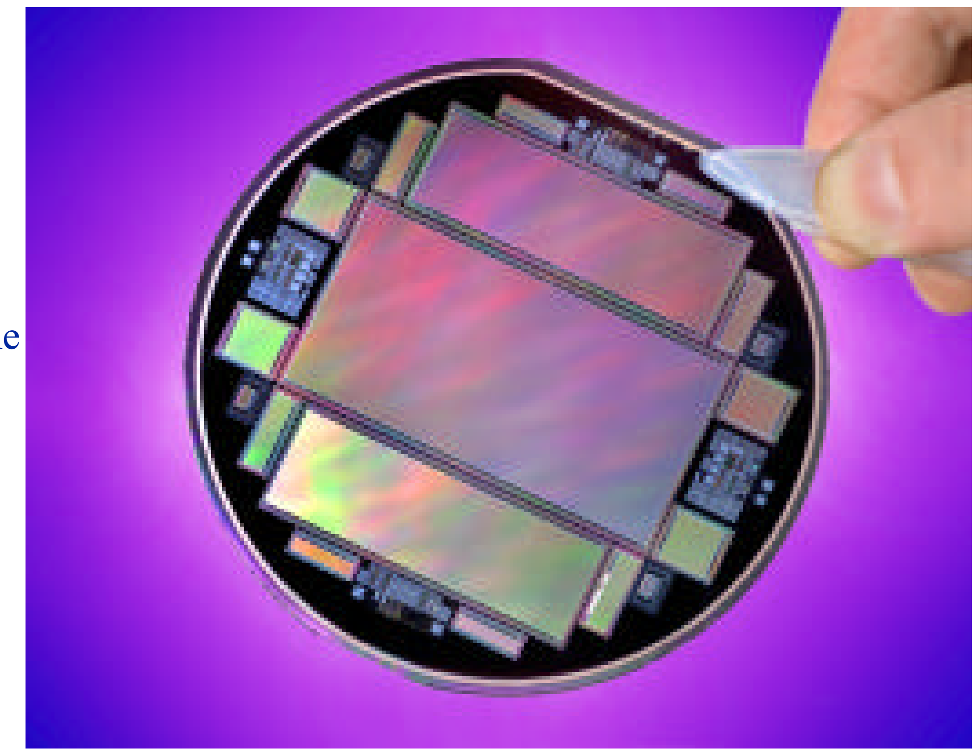


4 side abuttable.



CCD Status

- In house 2k x 2k (15 m pixels) design successful, meets SNAP performance requirements
- Commercialization at CCD foundry
  - 2k x 2k (15 m pixels) successful, in test at Lick
  - Two separate processing runs (1) “standard”; (2) modified process recipe
  - Current run of 4” wafers; will be followed immediately by run of 6” wafers
- Current in house fabrication completing now
  - 2k x 4k (15 m pixels) for Eschellette Spectrograph and Imager (Keck)
  - ~2k x 4k (12 m pixels)
  - ~2k x 4k (10.5 m pixels)



- Requires further extensive radiation testing (already tested at LBNL 88” cyclotron to 20% of SNAP lifetime exposure w/o degradation) & large scale prototyping
- Complete commercialization

Observatory

Simple Observatory consists of :

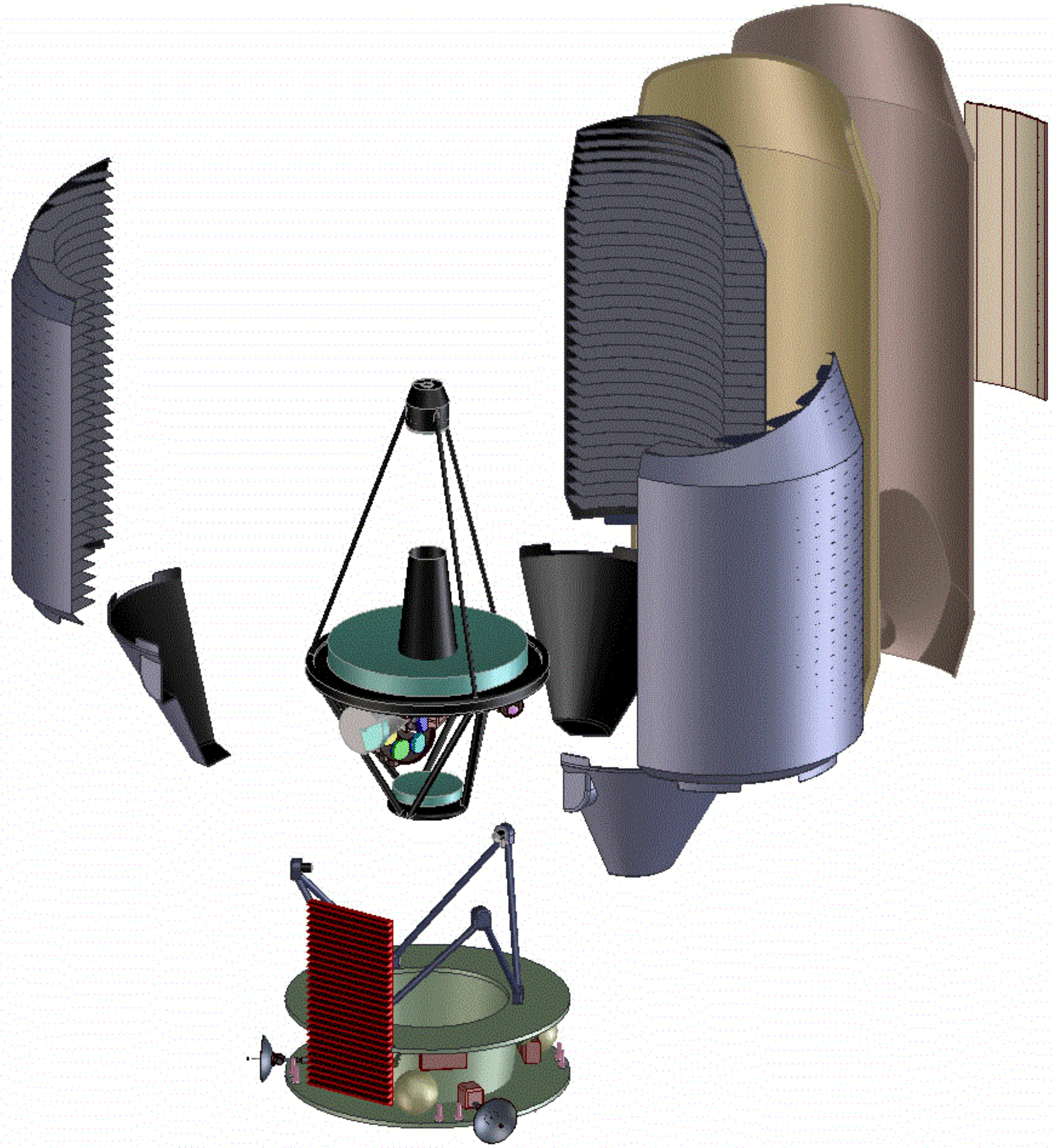
1) 3 mirror telescope w/ separable kinematic mount

2) Optics Bench w/ instrument bay

3) Baffled Sun Shade w/ body mounted solar panel and instrument radiator on opposing side

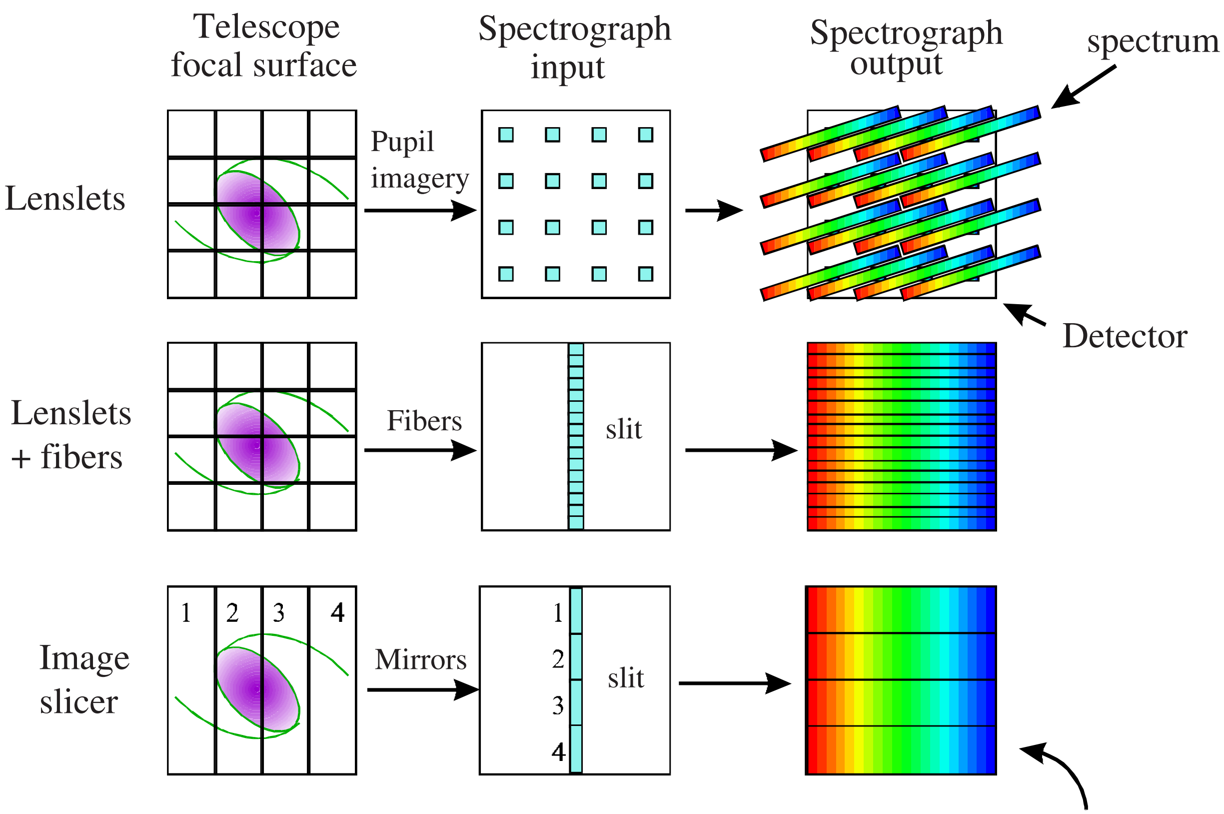
4) Spacecraft bus supporting telemetry (multiple antennae), propulsion, instrument electronics, *etc*

No moving parts (ex. filter wheels, shutters), rigid simple structure.

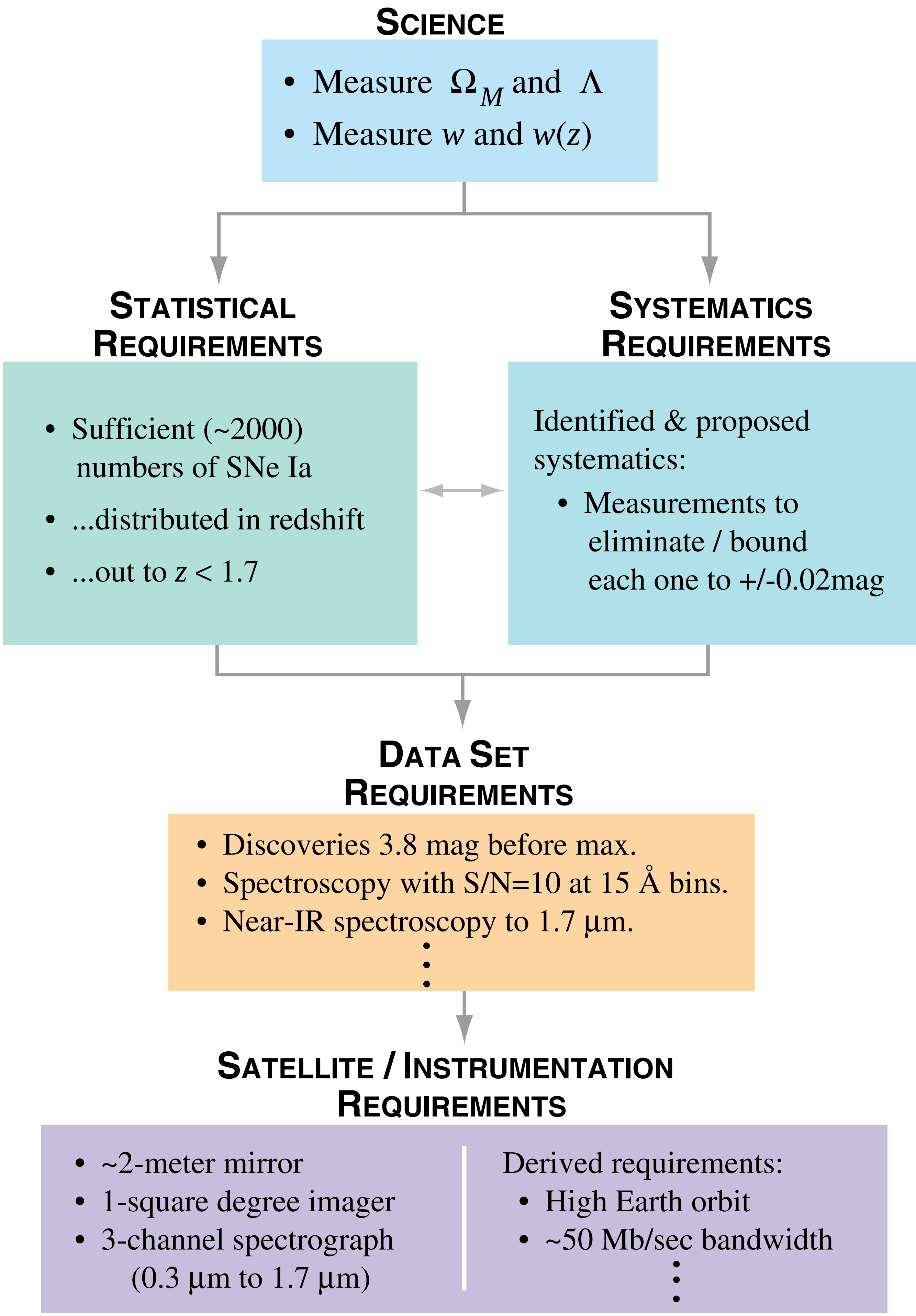


Spectroscopy Technology

Reflective Image Slicer (e.g. Palomar 200Ó, NGST IFMOS)



Only the image slicer retains spatial information within each slice/sample


SCIENCE
• Measure Ω_M and Λ
• Measure w and $w(z)$
STATISTICAL REQUIREMENTS
• Sufficient (~2000) numbers of SNe Ia
• ...distributed in redshift
• ...out to $z < 1.7$
SYSTEMATICS REQUIREMENTS
Identified & proposed systematics:
• Measurements to eliminate / bound each one to +/-0.02mag
DATA SET REQUIREMENTS
• Discoveries 3.8 mag before max.
• Spectroscopy with S/N=10 at 15 Å bins.
• Near-IR spectroscopy to 1.7 µm.
SATELLITE / INSTRUMENTATION REQUIREMENTS
• ~2-meter mirror
• 1-square degree imager
• 3-channel spectrograph (0.3 µm to 1.7 µm)
Derived requirements:
• High Earth orbit
• ~50 Mb/sec bandwidth

SNAP SuperNova Acceleration Probe

First-principles comparison: space vs. ground

		SNAP	LSST/DMT	Space / Ground Efficiency Ratio	
Telescope Aperture	D	2 m	6.5 m	$\left(\frac{D_{space}}{D_{ground}}\right)^2 =$	1/10
Seeing (RMS avg)	σ	0.1"	0.8"	$\left(\frac{\sigma_{space}}{\sigma_{ground}}\right)^{-2} =$	64
Sundown Fraction	f	98%	40%	$\frac{f_{space}}{f_{ground}} =$	2.5
Field size (solid angle)	Ω_{field}	1 sq-deg	7 sq-deg	$\frac{\Omega_{space}}{\Omega_{ground}} =$	1/7
Sky background (n_γ)	Σ_B	4.1×10^{-7}	4.7×10^{-6}	$\left(\frac{\Sigma_{space}}{\Sigma_{ground}}\right)^{-1} =$	11
	Σ_V	4.8×10^{-7}	3.6×10^{-6}		7
	Σ_R	4.9×10^{-7}	4.4×10^{-6}		9
	Σ_I	4.6×10^{-7}	7.8×10^{-6}		17
	Σ_Z	4.0×10^{-7}	2.0×10^{-5}		50
	Σ_J	3.1×10^{-7}	1.3×10^{-4}		441

Multi-object photometry & discovery

 # SNe measured at a given s/n in a given time
(for sky-noise limited case):

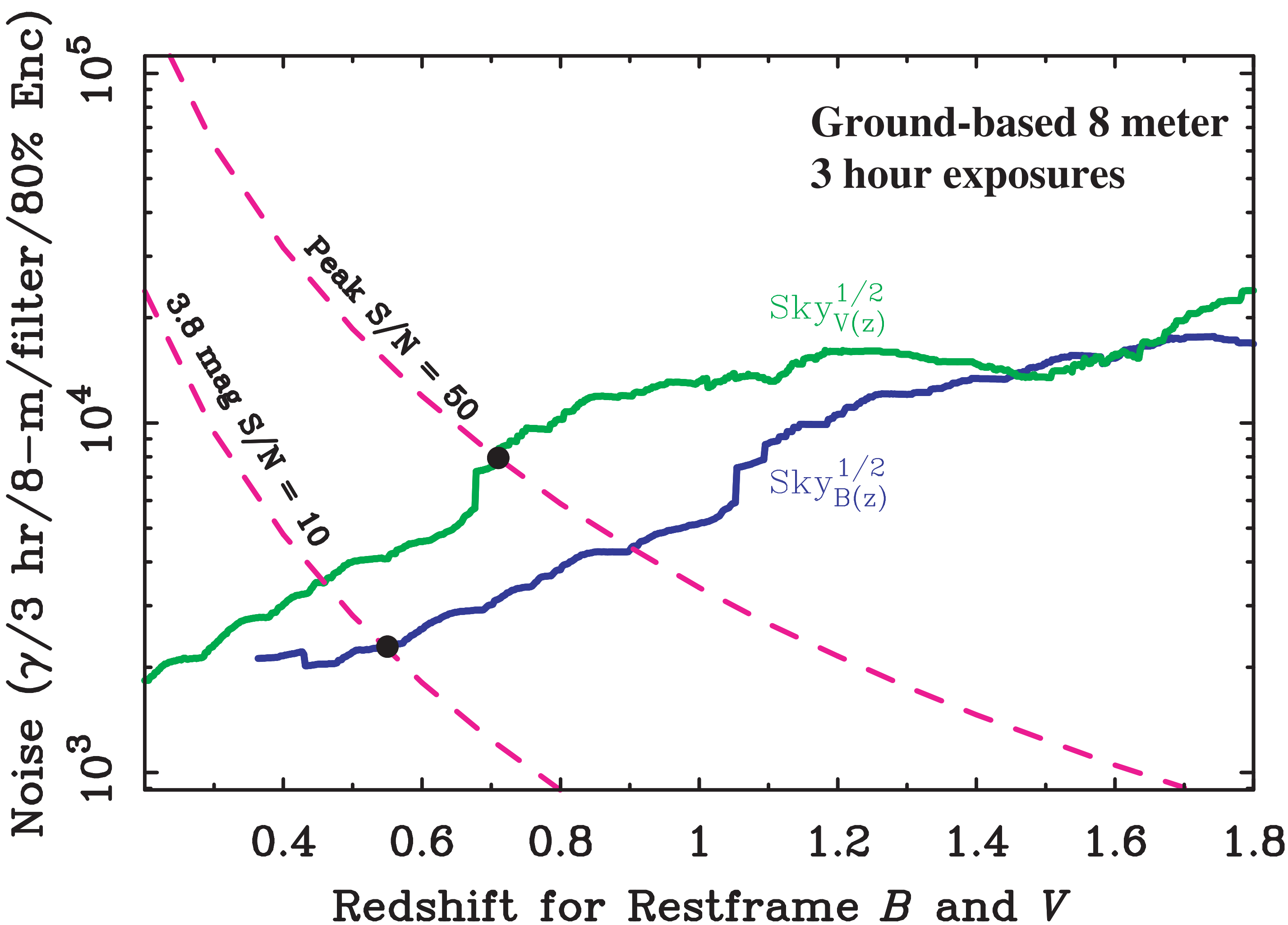
$$\propto \frac{D^2 \, f \, \Omega_{field}}{\sigma^2 \, \Sigma} = \sim 2\Sigma^{-1}$$

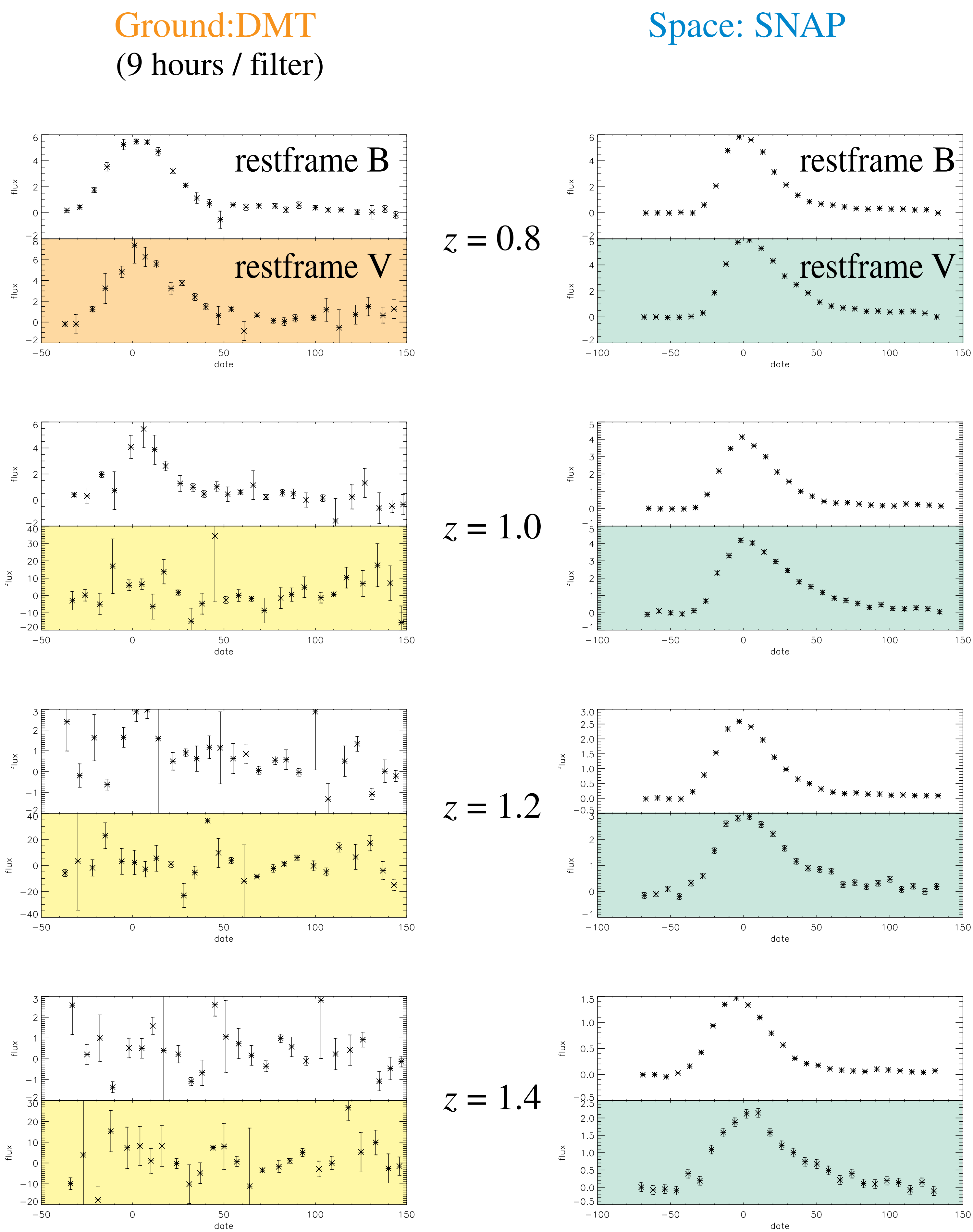
Why a New Satellite?

From the ground, the sky photon noise limits the range of redshifts to:

--- $z \sim 0.55$ for discovery near explosion date.

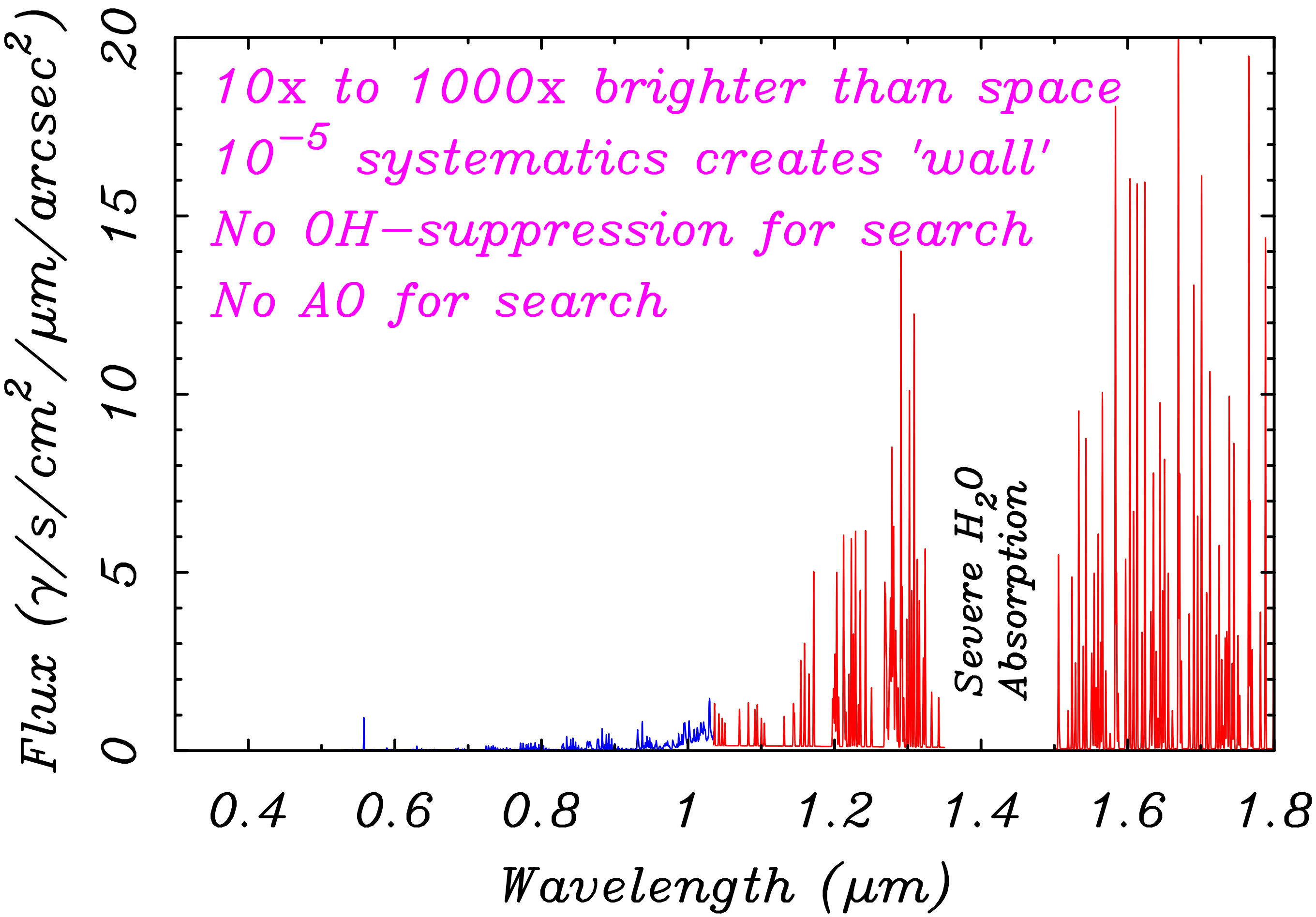
--- $z \sim 0.7$ for 2% photometry of color at max.



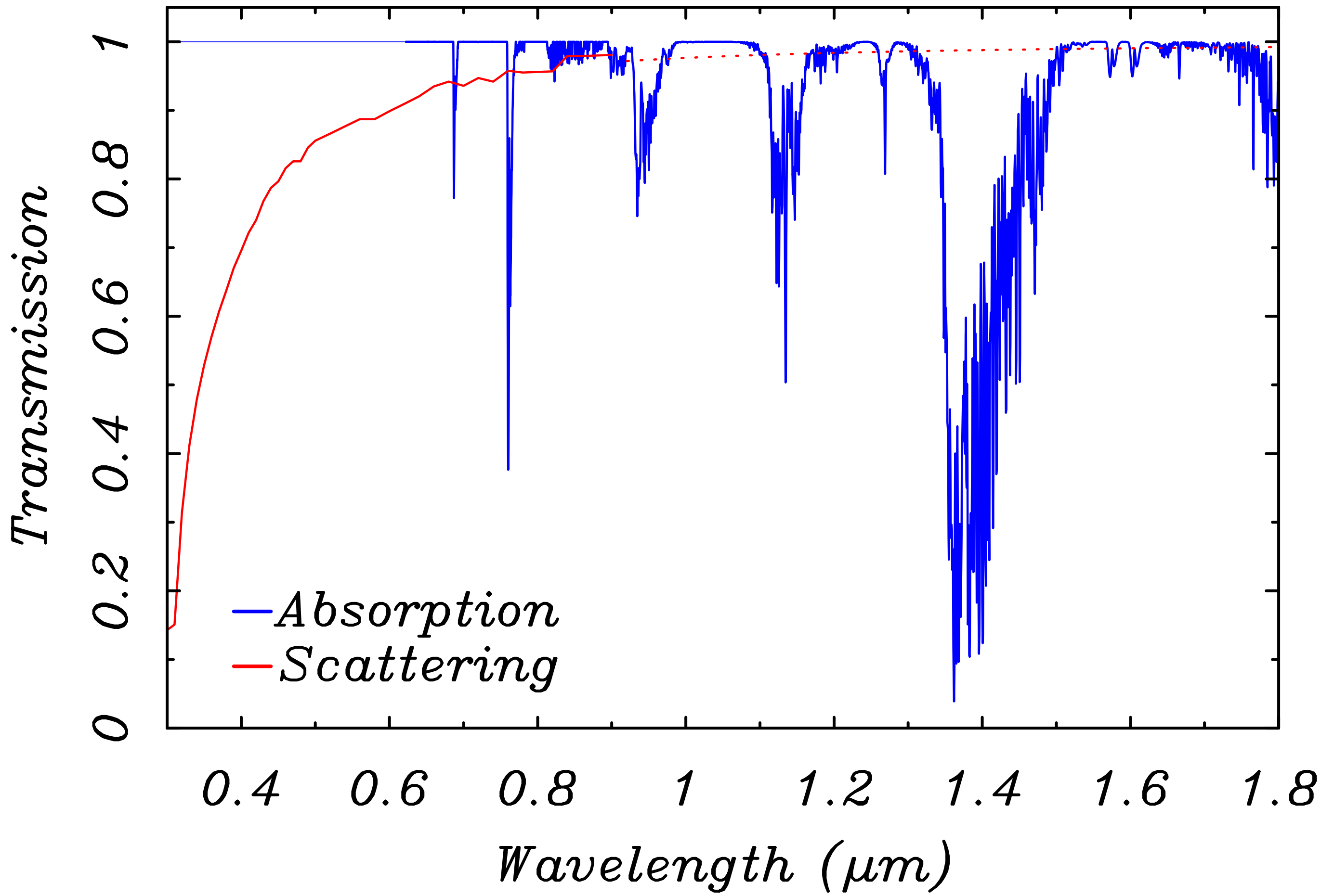


Ground:DMT
(9 hours / filter)
Space: SNAP
restframe B
restframe V
z = 0.8
z = 1.0
z = 1.2
z = 1.4
flux
date

the Tremendous Sky Brightness compared to SNe

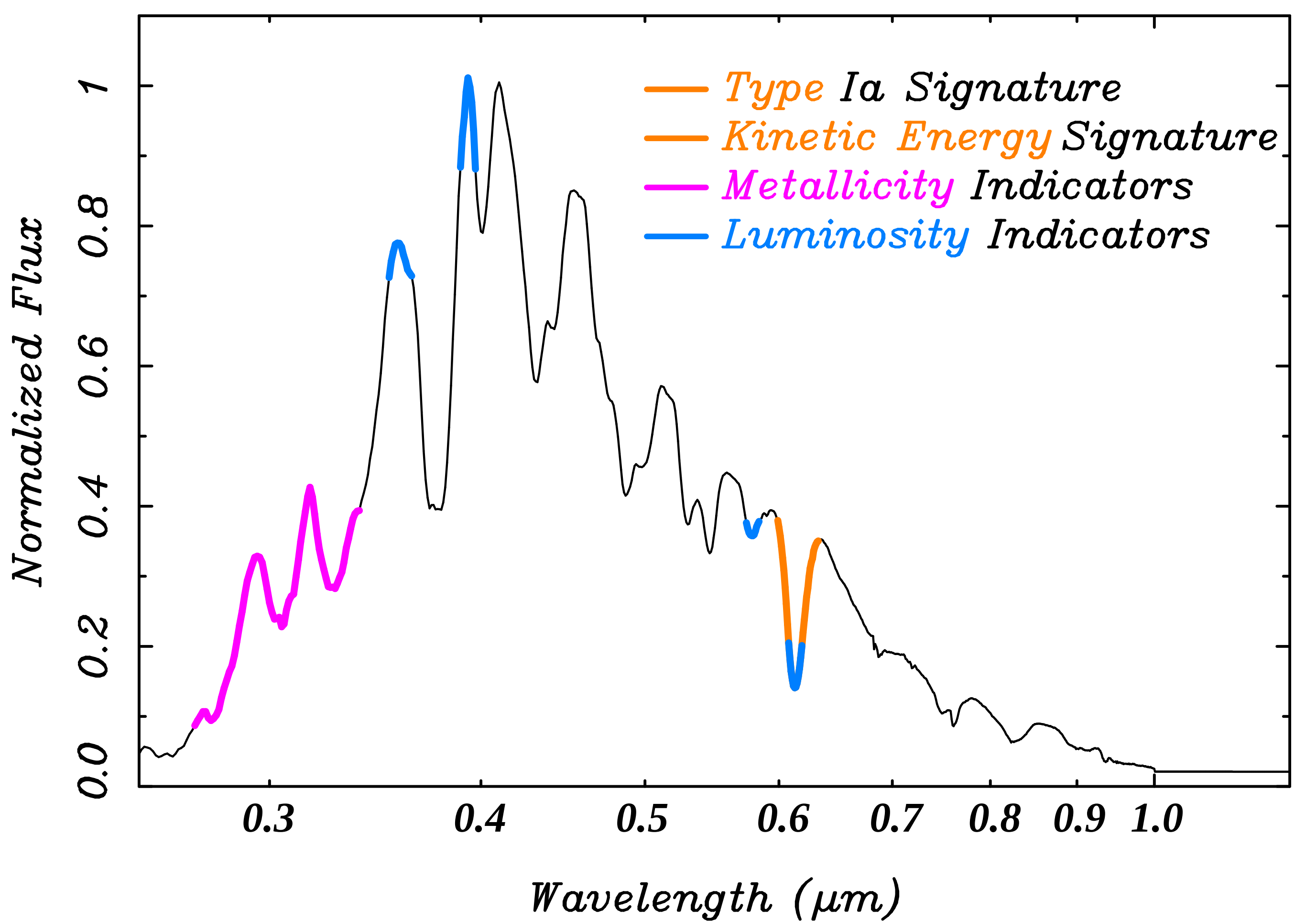


Atmosphere Compromises Quality & Homogeneity



SNAP SuperNova Acceleration Probe

Type Ia Spectral Features



SNAP SuperNova Acceleration Probe

Weak Gravitational Lensing from Space

Weak gravitational lensing by large-scale structures in the universe produces coherent distortions in the shapes of background galaxies. It can be used to

directly map the projected distribution of dark matter,
measure cosmological parameters (esp. σ_8 and Ω_M)
and the power spectrum of matter density fluctuations
--- and thus constrain the nature of dark matter.

This effect has recently been detected from the ground by 4 independent groups. These experiments require high precision measurements of the shape of faint galaxies and are thus limited by seeing; they are already within a factor of three of being systematics limited (which will be reached within ~1 year).

They can thus can be dramatically improved by SNAP's wide-field observations with a much reduced PSF. Based on HST studies, this will lead to:

a larger surface density of resolved galaxies n_g: 15 --> 50 -- 100
a larger median redshift for the galaxies z_g: 0.8 --> 1.1 --1.4
a smaller scatter in the deconvolved ellipticities of the galaxies (more shape information) σ_ε: 0.4 --> 0.2 -- 0.3

An improved sensitivity to the weak lensing shear:

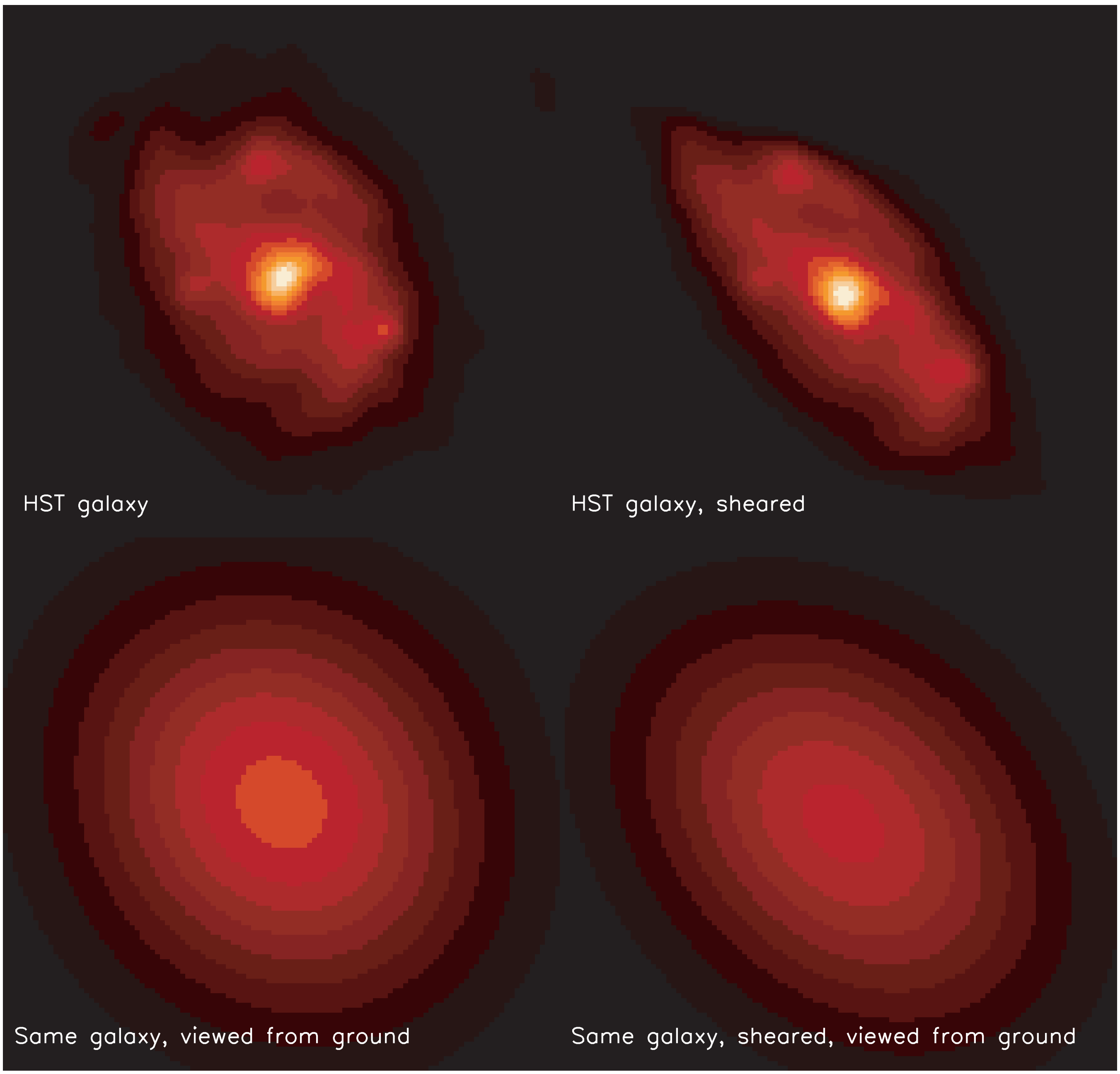
$$SNR_\gamma \sim n_g^{0.5} \; z_g^{0.7} \; \sigma_\varepsilon^{-1}$$

larger by a factor of about 3--8. This corresponds to an improvement for the SNR for $\Omega_M \sigma_8^{1.7}$ of about 1.5 x SNR_γ = ~5--11, for the same survey area.

In addition, the smaller PSF will make the shear measurement less sensitive to systematics (esp. uncertainty in the PSF shape).

SNAP SuperNova Acceleration Probe

Weak lensing galaxy shear observed from space
versus
Weak lensing galaxy shear observed from the ground.



SNAP SuperNova Acceleration Probe

Weak Gravitational Lensing from Space

will achieve the following goals, which are unfeasible from the ground:

A high sensitivity map of the projected dark matter density.
-- resolving the cosmic web (filaments, voids, etc).

A high-precision, reliable measurements of the lensing power spectrum.
-- Improvement in SNR for $\Omega_M \sigma_8^{1.7}$ *of 5 -- 11 for a given survey area.*

A precise and reliable measurement of the higher-order statistics of the dark matter distribution (skewness, kurtosis, etc).
-- measurement of Λ*, and test of the gravitational instability paradigm.*

Using colors, a measurement of weak lensing at different redshift slices.
-- measurement of the evolution of structures from $z \sim 1$ *to 0.*

SNAP SuperNova Acceleration Probe

Status: Recent Technical Progress

Initial industrialization of CCD manufacturing.

High-resistivity CCDs successfully tested
to 10x mission-lifetime proton irradiation dose.

Mechanical and assembly concept for GigaCam.

Recent submission of read-out chip design as
a miniaturized custom integrated circuit.

Successful optical design.

Finite-element analysis of telescope
to study stability/jitter.

Engaged Michael Krim (lead designer and
systems engineer for Hubble telescope)
to help develop telescope manufacturing
and testing concepts.

SNAP Proposal Signatories

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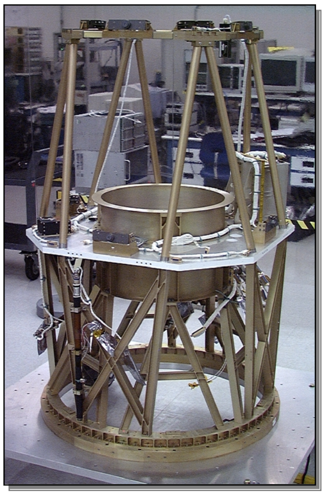
CENTRA, Instituto Superior Tecnico, Lisbon, Portugal

Space Sciences Laboratory

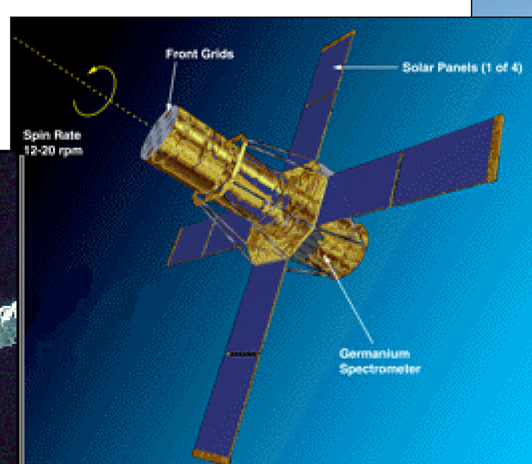
- Complete Satellites
- Satellite Instruments & Science Complements
- Mission and Science Operations Centers
- Employing 420 Scientists, Engineers, and Staff

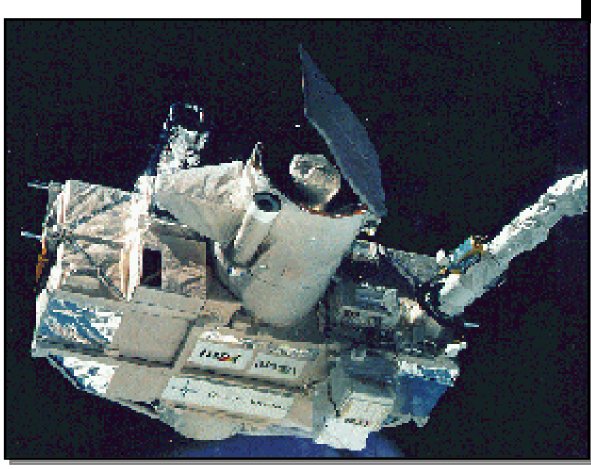


Facilities

- 55000 sq. ft. Office and Laboratory Space
- On-Site Machine Shop
- Clean Room Facilities to Class 100
- Thermal Vacuum Facilities to 3m diameter
- Spacecraft Integration Facility
- 4-story High Bay
- Radiation Sources Lab

- Secure High Speed Communications to NASA Ground Network
- Ground Station Operations
- 11-meter S-Band Antenna with X-band capability
- Autonomous Operations
  - Pass Supports
  - Orbit Determination & Tracking
  - Emergency Response System





Space Sciences Laboratory

Complete Missions

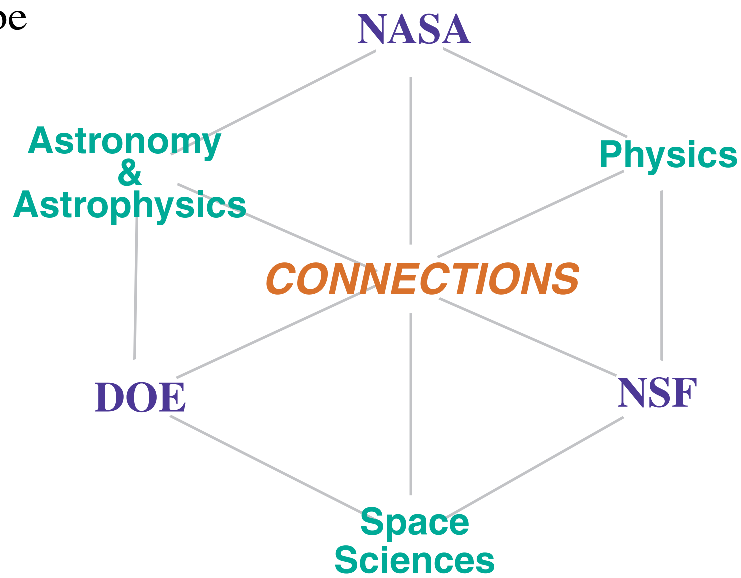
Extreme Ultra Violet Explorer (EUVE)
Fast Auroral SnapshoT (FAST)
High Energy Solar Spectroscopic Imager (HESSI)

	EUVE	*FAST*	*HESSI*
Project Management	●		●
Spacecraft Bus			●
Mission Operations	●	●	●
Science Operations	●	●	●
Ground Data Systems	●		●
Science Package	●	●	●
Electronics	○	○	○
Telescopes	○		
Electric Field &		○	○
Particle Instruments		○	
Imager			○
Spectrometer			○

Recent Flight Instruments

- CRRES LP
- Polar EFI
- Wind 3DP
- Cluster I EFW, CIS
- Cluster II EFW, CIS
- Image FUV, WIC
- Mars Observer ER
- Mars Global Surveyor ER
- Ulysses LAN
- Lunar Prospector ER
- FUSE
- SOHO UVCS & SUMER
- GALEX
- COS

SNAP SuperNova Acceleration Probe



How does a project get proposed and prioritized by peer-review in this multi-disciplinary, multi-agency "Connections" environment?

The NRC astronomy decadal survey suggested a mechanism for such multi-agency cooperation:

"The survey committee recommends that each agency build on its own unique capabilities while recognizing those of related agencies, taking steps toward collaborations that it believes will prove fruitful. Each agency should have a strategic plan (such as DOE and NSF's SAGENAP and NASA's SScAC) available to evaluate proposed interagency collaborations. The Office of Science Technology and Technology Policy (OSTP) could facilitate such interagency collaborations."

SNAP SuperNova Acceleration Probe

Project Chronology

First public presentation of idea at Fermilab "Inner Space/Outer Space" symposium.	**end of May 1999**
Letter of Intent (pre-proposal) to DOE & NSF-Physics	**Nov 1999**
Review panel for Letter of Intent	**Dec 1999**
Science proposal for study phase to DOE & NSF-Physics	**Feb 2000**
SAGENAP review for DOE & NSF-Physics	**end of March 2000**
SAGENAP peer review panel report	**July 2000**
Study proposal to NSF-Physics Review in process.	**end of Sept 2000**
Study review for DOE	**(scheduled) Jan 2001**

SNAP SuperNova Acceleration Probe

Peer Review by the DOE and NSF's SAGENAP panel.

(Reports to HEPAP to establish High Energy Physics' priorities, parallel to Decadal Survey establishing Astronomy's priorities).

The project was successfully reviewed by SAGENAP March 29-31, 2000; panel's report released July 21, 2000:

"In summary, the SAGENAP discussions indicate enthusiastic agreement by the panel that the **science goals** are on questions of great **importance to physics and cosmology**. Further, it was considered that at the present stage in the measurement of the cosmological parameters, **new experimentation** is fully warranted and that the **SN Ia technique** will continue to play a crucial part. The quality of the document presented was felt to be impressive, particularly for a project in its early stages. The panel members were **favorably impressed** with the proposers' consideration of the sources of **systematic error** and were largely convinced that a fully **satellite-based experiment** is likely to be the preferred approach."

"There was unanimity on SAGENAP that a substantial R&D program is required soon to insure a successful SNAP experiment…. SAGENAP suggests that interim funds be provided to speed the preparations for a review and to enable the forward movement of this important experiment. Such movement should also include efforts to clarify and facilitate the opportunities for launch of the satellite."

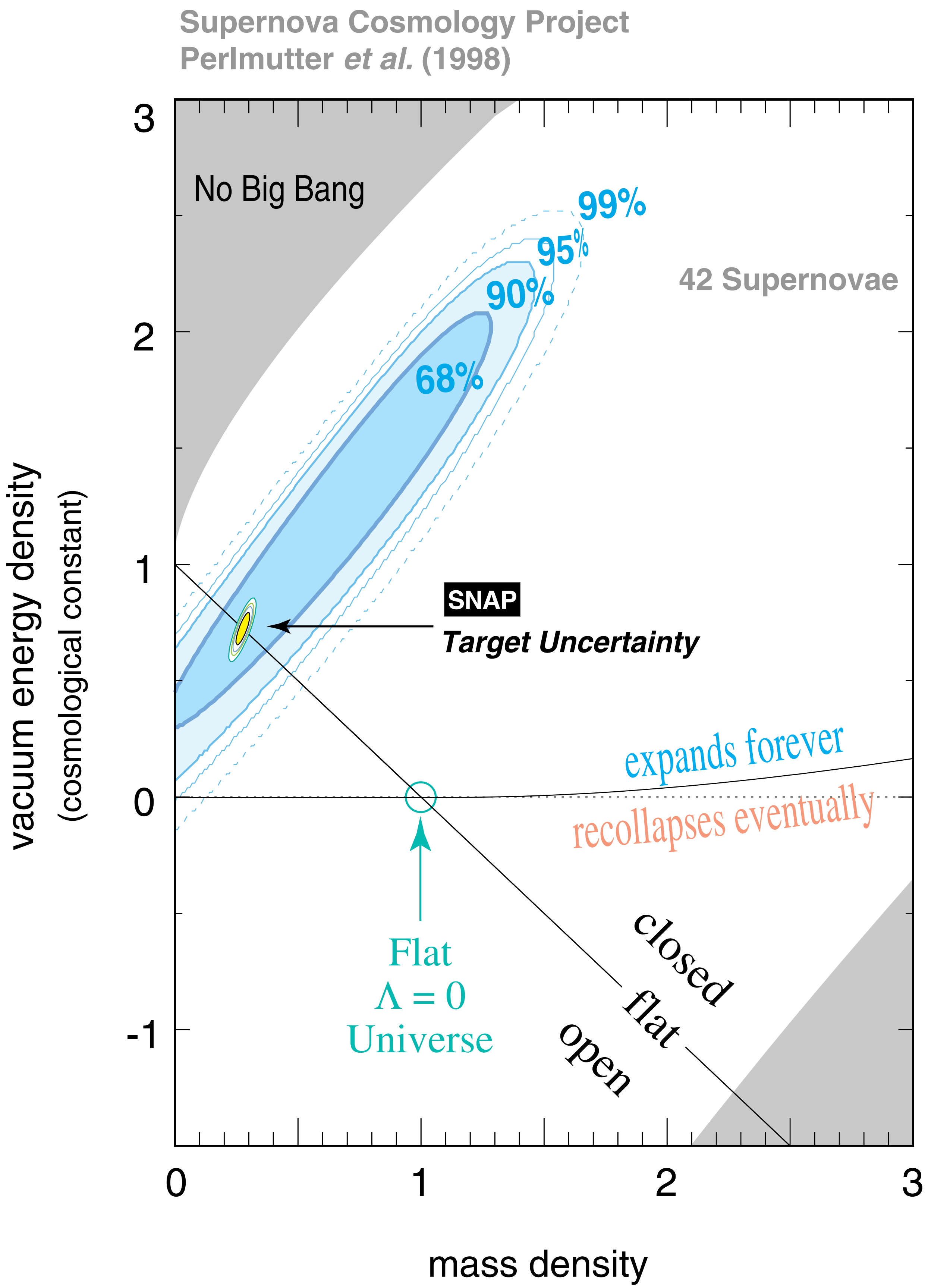
SNAP SuperNova Acceleration Probe

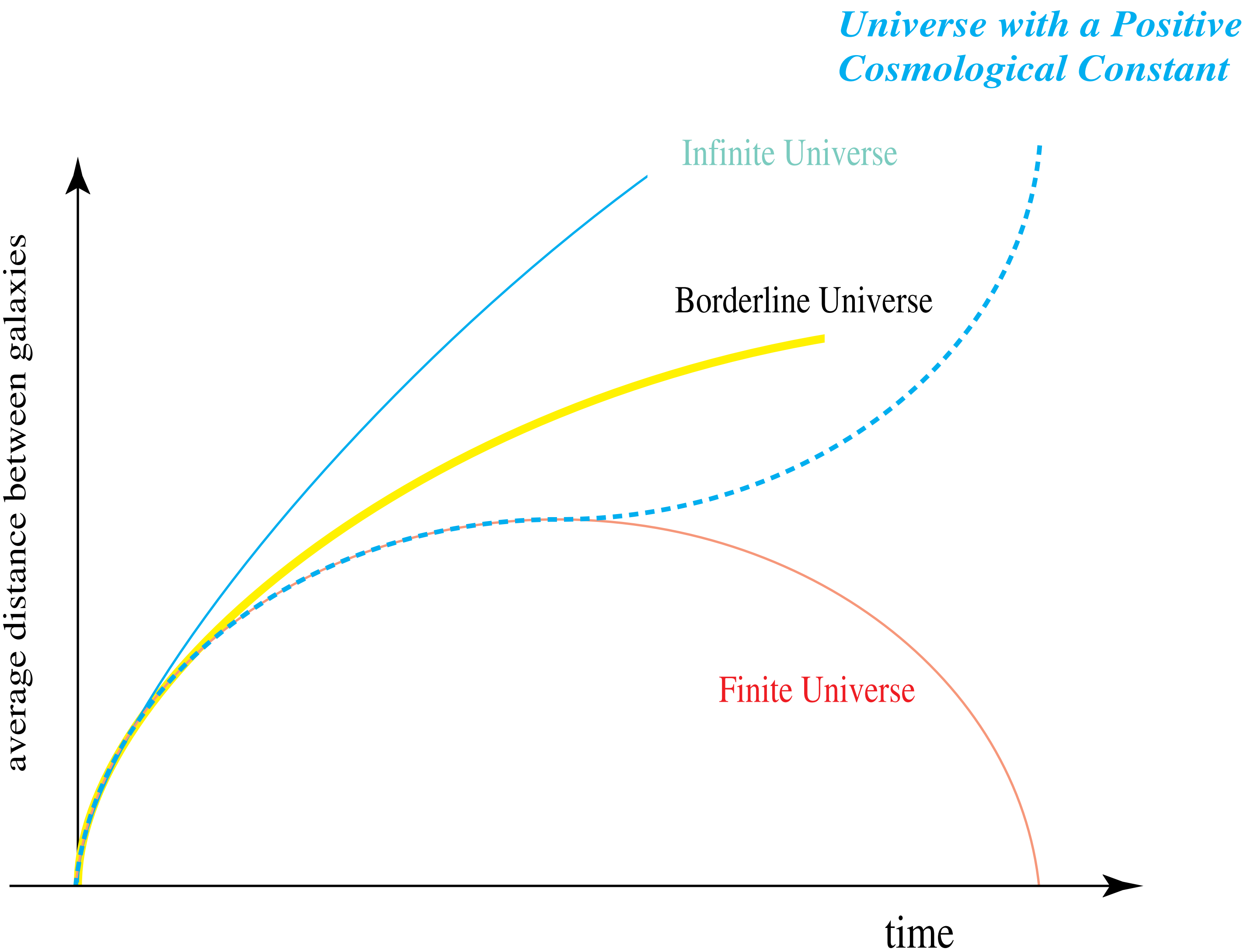
Comments from the NRC Astronomy Decadal Survey on the *science* of the SNAP mission:

"The committee identified several key problems that are particularly ripe for advances in the coming decade. These problems are … properties of the universe: the amount and distribution of its matter and energy, its age, and the history of its expansion."

"Important findings include … the recognition that most of the matter in the Universe reside in some mysterious unseen form ("dark matter"), perhaps a new kind of elementary particle, and the recent evidence that a novel form of "dark energy" dominates the dynamics of the cosmic expansion. The committee agreed that astronomers and astrophysicists can reasonably anticipate a number of future interactions with physics in the realms of … searching for new physics such as new particles, new forces and the unification of forces."

SNAP's conceptual phase postdated the decadal survey data collection phase, so it was not explicitely discussed.


Supernova Cosmology Project
Perlmutter et al. (1998)
No Big Bang
99%
95%
90%
68%
42 Supernovae
SNAP
Target Uncertainty
expands forever
recollapses eventually
Flat
Λ = 0
Universe
closed
flat
open
vacuum energy density
(cosmological constant)
mass density
3
2
1
0
-1
0
1
2
3


Universe with a Positive
Cosmological Constant
Infinite Universe
Borderline Universe
Finite Universe
average distance between galaxies
time