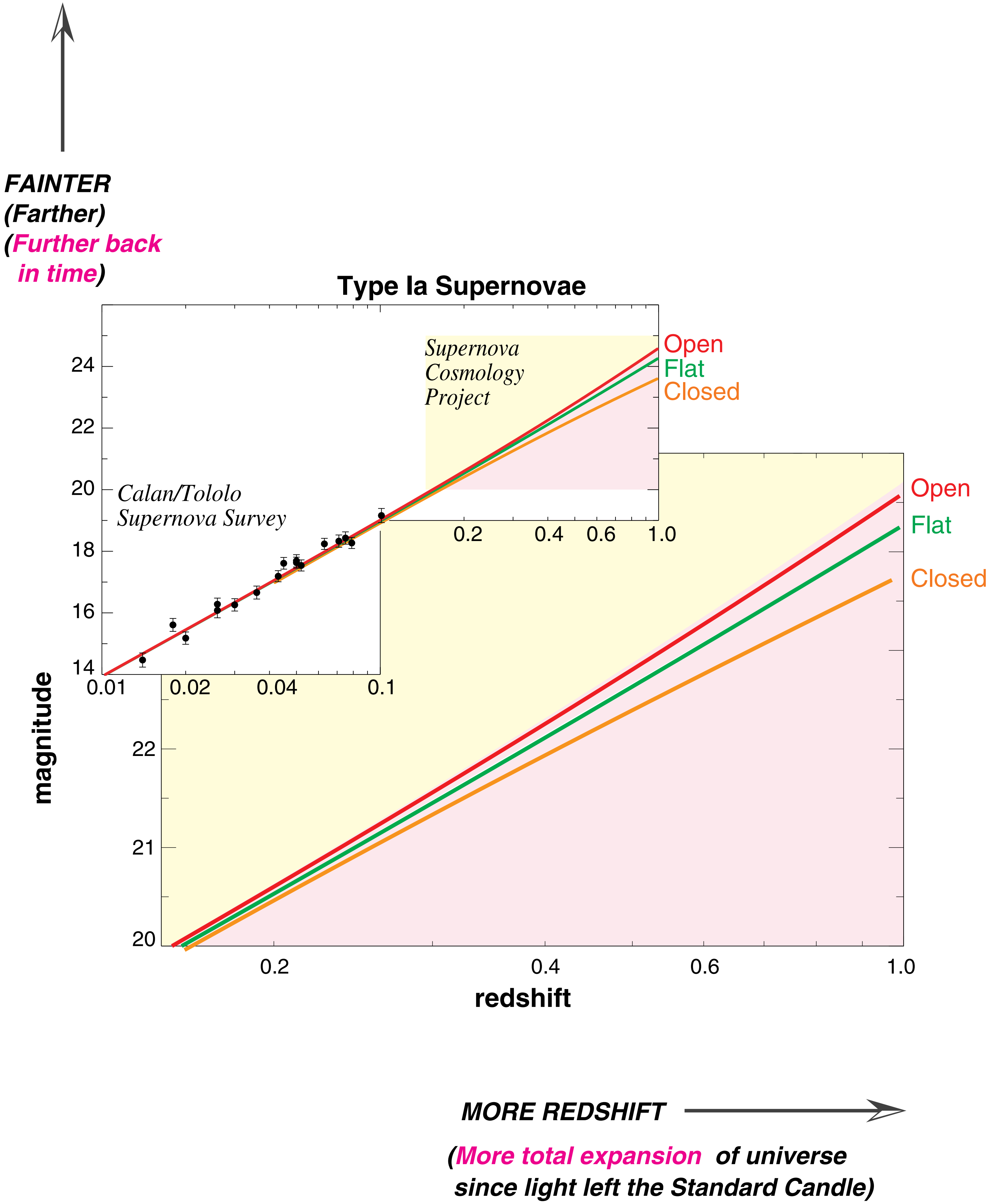
SNAP SuperNova Acceleration Probe

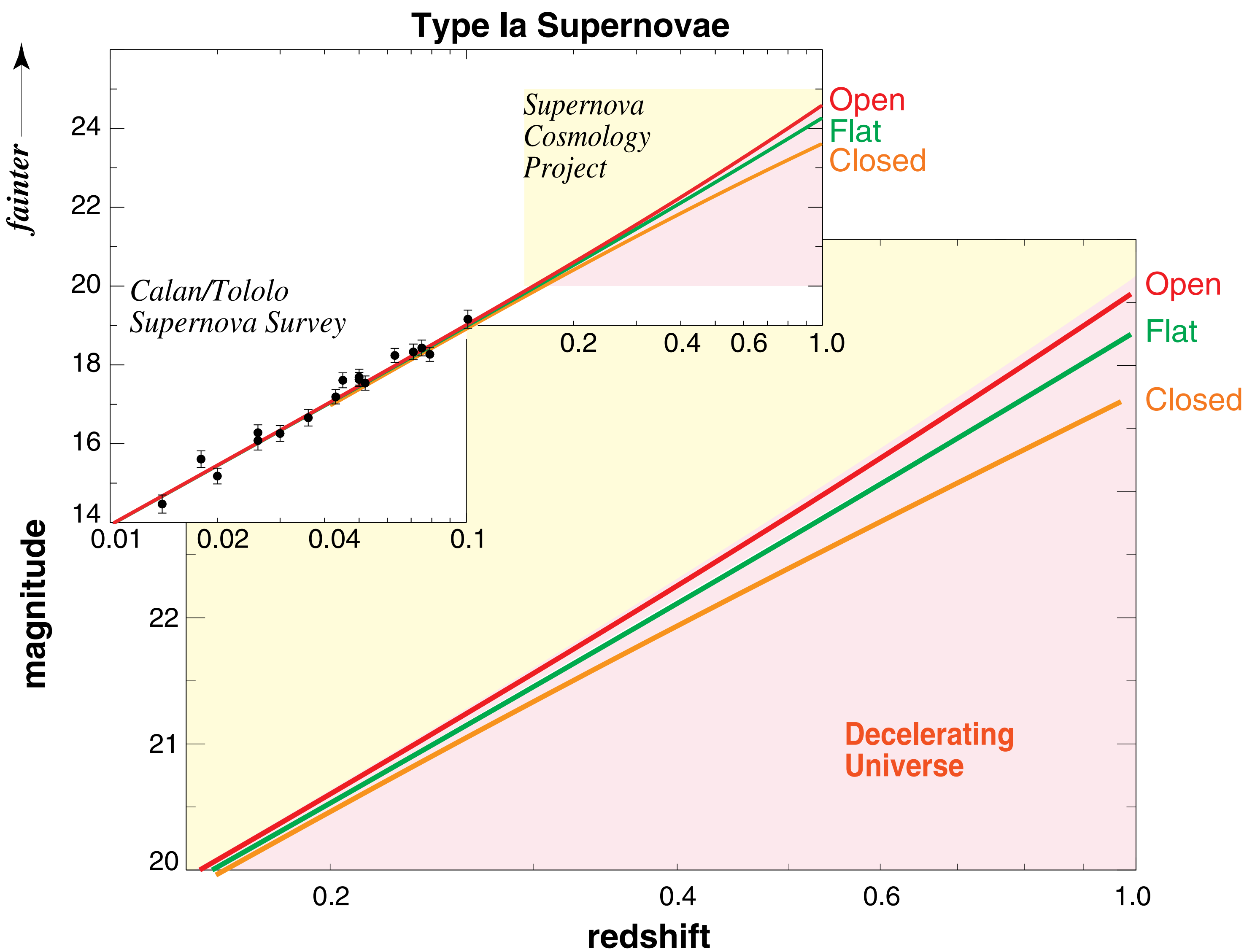
Presentation to NASA's
Structure and Evolution
of the Universe Subcommittee
December 2001

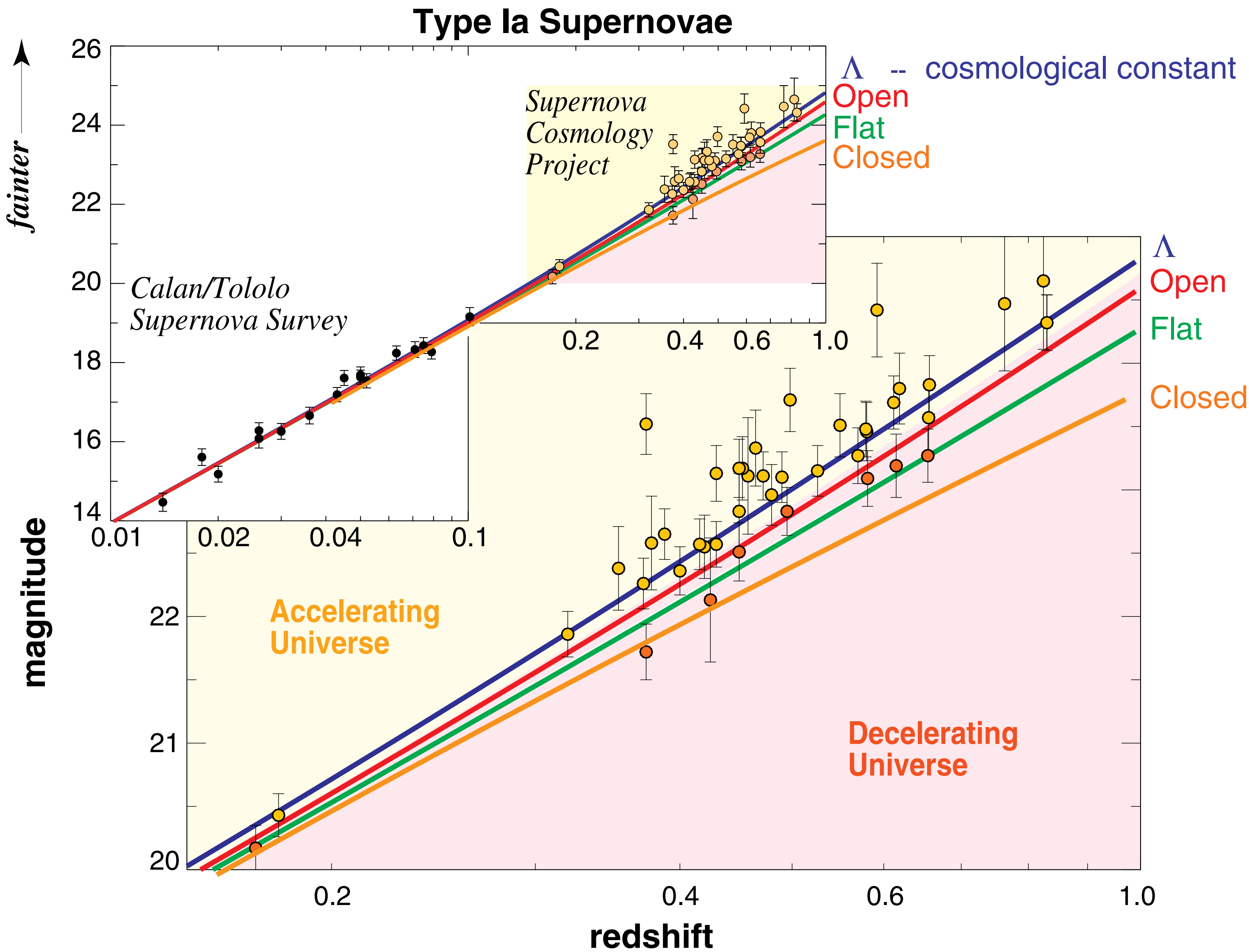
Saul Perlmutter
for the SNAP Collaboration

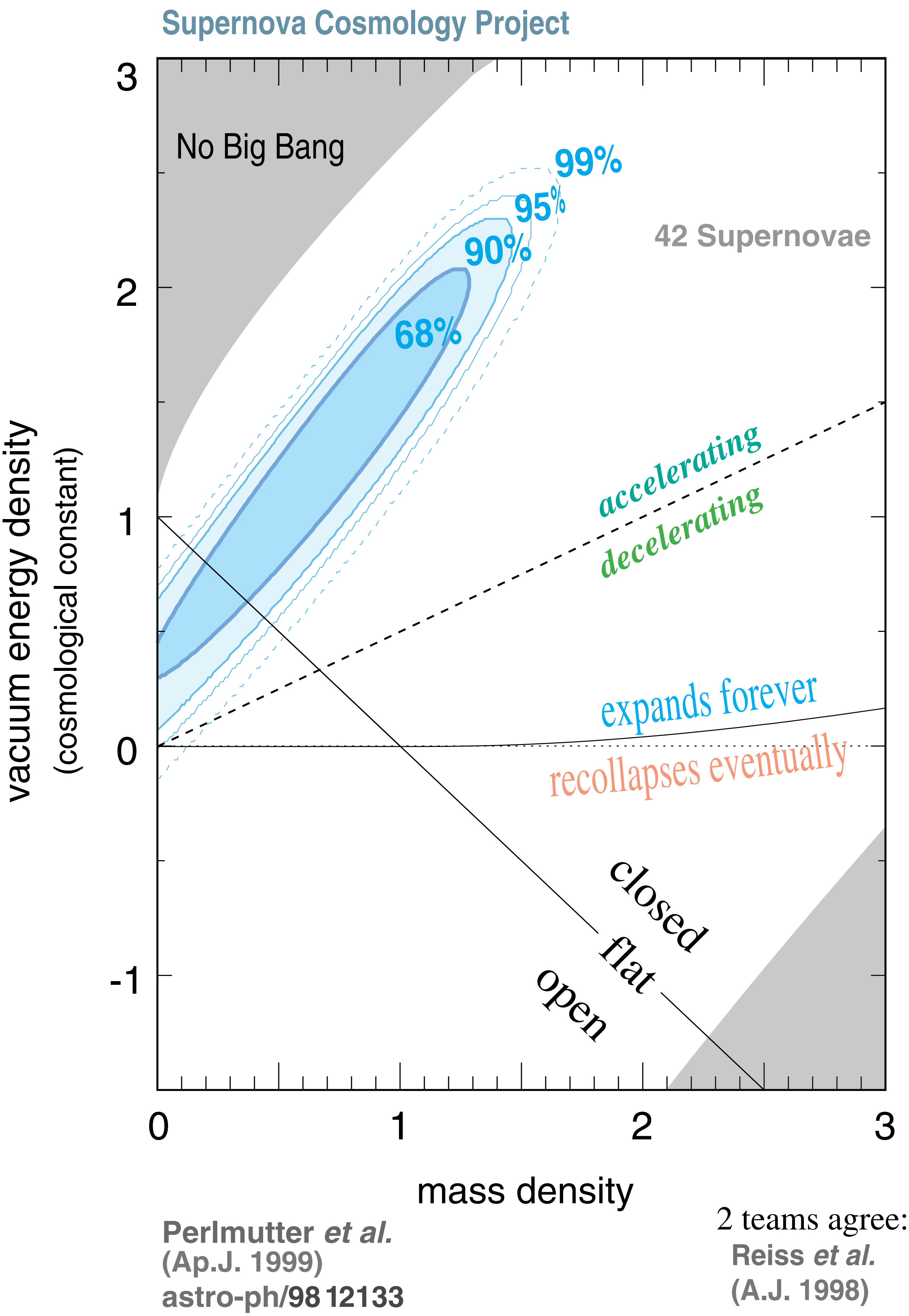
0. Background: cosmology/dark energy measurements from supernovae.
1. SNAP irreducible science goal: $w'(z)$.
2. Why does this goal require SNAP?
3. Current technical status.
4. Project status & how SNAP fits in the science scene.

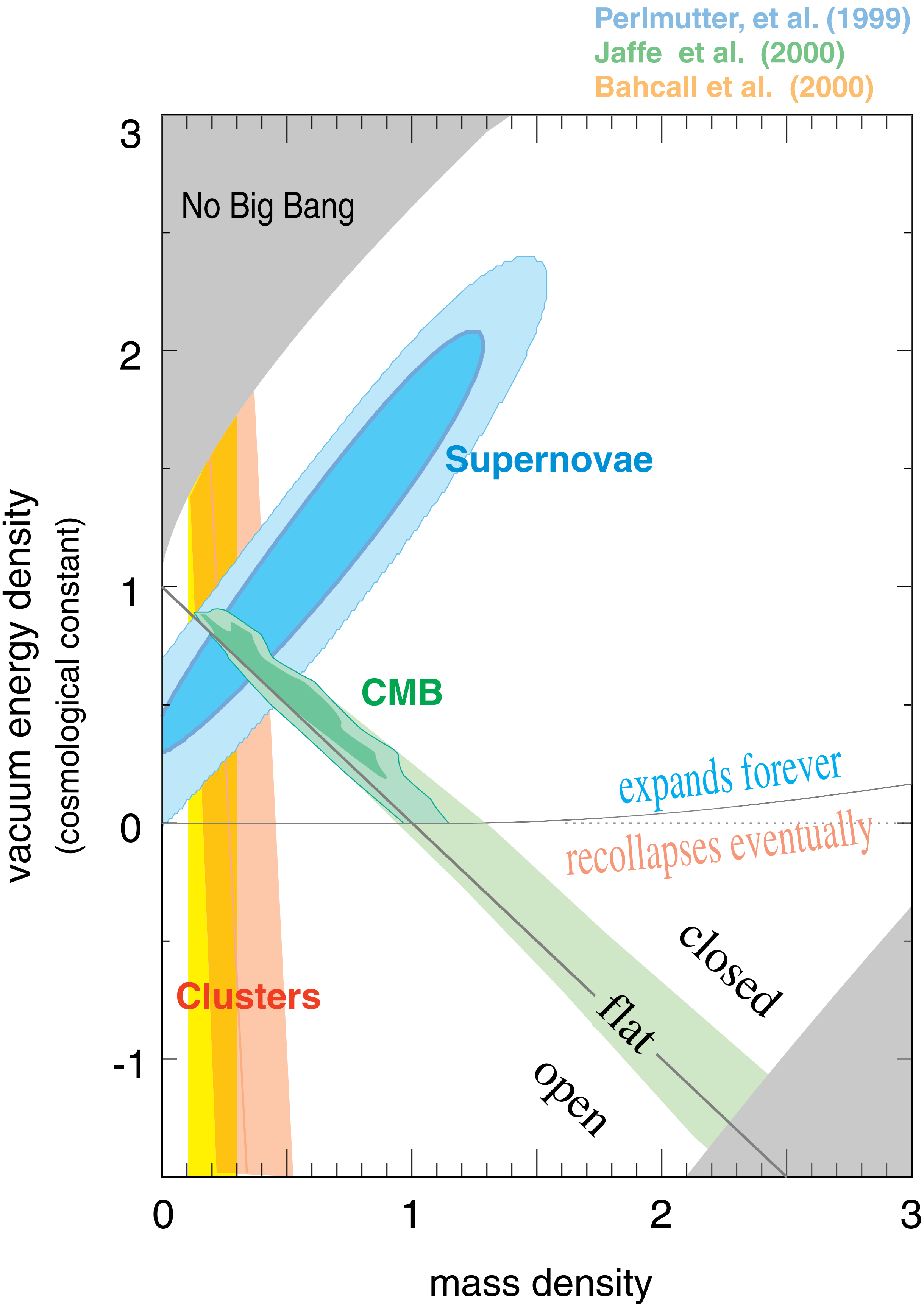


FAINTER
(Farther)
(Further back in time)
Type Ia Supernovae
Supernova Cosmology Project
Calan/Tololo Supernova Survey
Open
Flat
Closed
magnitude
redshift
MORE REDSHIFT
(More total expansion of universe since light left the Standard Candle)


Type Ia Supernovae
fainter
magnitude
redshift
Supernova
Cosmology
Project
Calan/Tololo
Supernova Survey
Open
Flat
Closed
Decelerating
Universe
24
22
20
18
16
14
0.01
0.02
0.04
0.1
0.2
0.4
0.6
1.0
21


Type Ia Supernovae
fainter
magnitude
redshift
Calan/Tololo
Supernova Survey
Supernova
Cosmology
Project
Λ -- cosmological constant
Open
Flat
Closed
Λ
Open
Flat
Closed
Accelerating
Universe
Decelerating
Universe
26
24
22
20
18
16
14
0.01
0.02
0.04
0.1
0.2
0.4
0.6
1.0
22
21
20
0.2
0.4
0.6
1.0


Supernova Cosmology Project
No Big Bang
99%
95%
90%
68%
42 Supernovae
accelerating
decelerating
expands forever
recollapses eventually
closed
flat
open
vacuum energy density
(cosmological constant)
mass density
3
2
1
0
-1
0
1
2
3
Perlmutter et al.
(Ap.J. 1999)
astro-ph/98 12133
2 teams agree:
Reiss et al.
(A.J. 1998)



Perlmutter, et al. (1999)
Jaffe et al. (2000)
Bahcall et al. (2000)
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

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).

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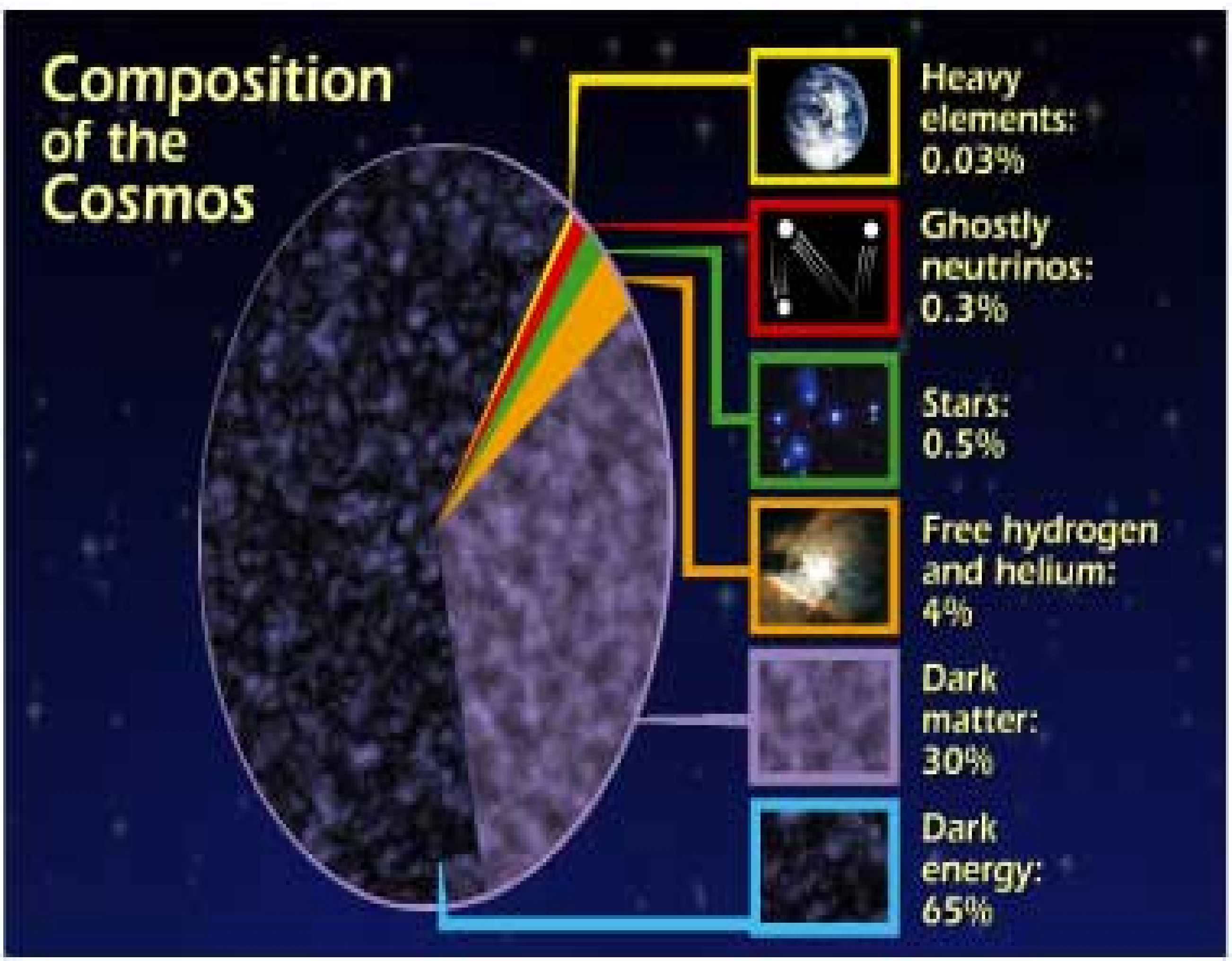


Physicists see Vacuum Energy/Cosmological Constant
as one of the key problems of our day:

"Right now, not only for cosmology but for elementary particle theory, this is the bone in our throat."

—Steven Weinberg

"...Maybe the most fundamentally mysterious thing in basic science."

—Frank Wilczek

"...Would be No. 1 on my list of things to figure out."

—Edward Witten

"Basically, people don't have a clue as to how to solve this problem."

—Jeff Harvey

"This is the biggest embarrassment in theoretical physics,"

—Michael Turner

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

Two coincidences:

- ***Why so small?***

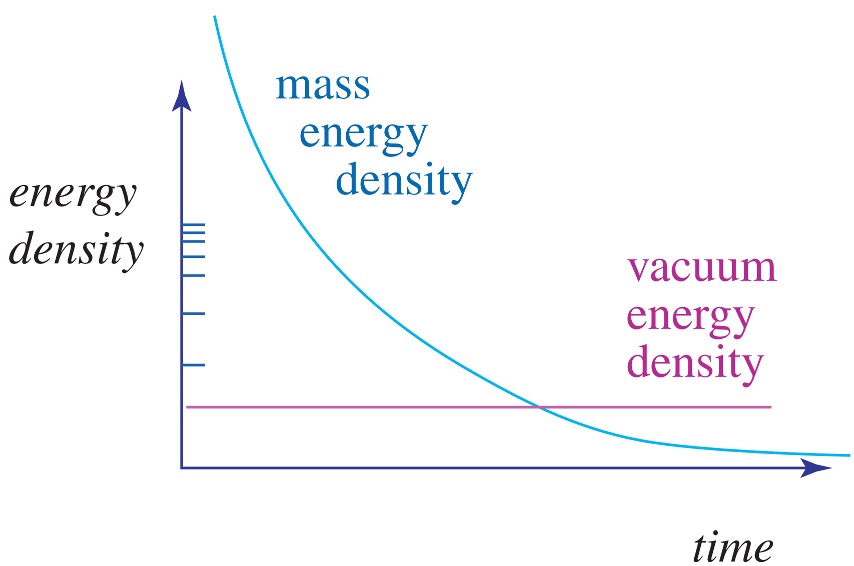
  Might expect $\frac{\Lambda}{8\pi G} \sim m^4_{\text{Planck}}$

  This is off by ~120 orders of magnitude!

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

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

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



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What are the alternatives?

New Physics:

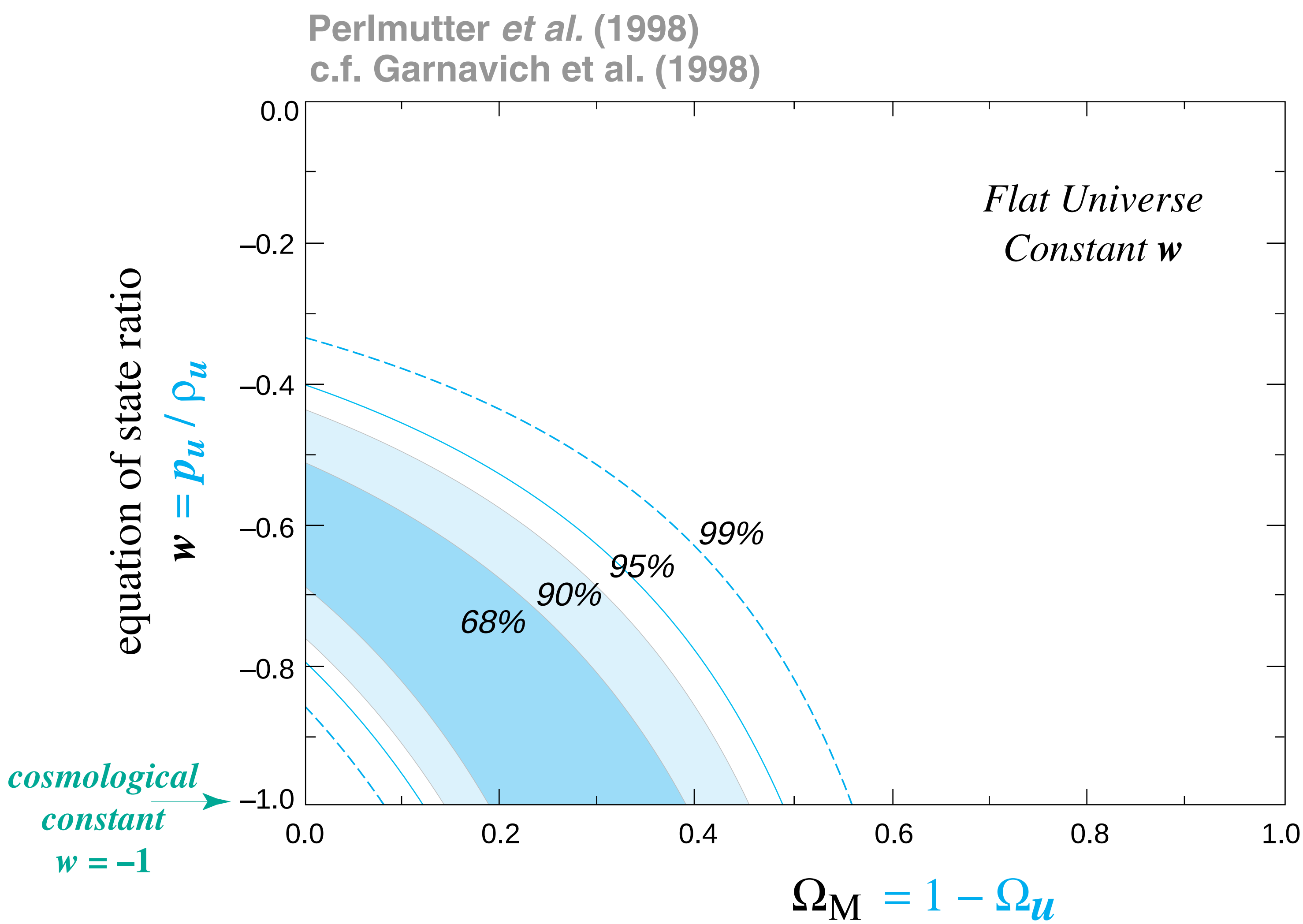
"Dark energy": Dynamical scalar fields, "quintessence",...

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

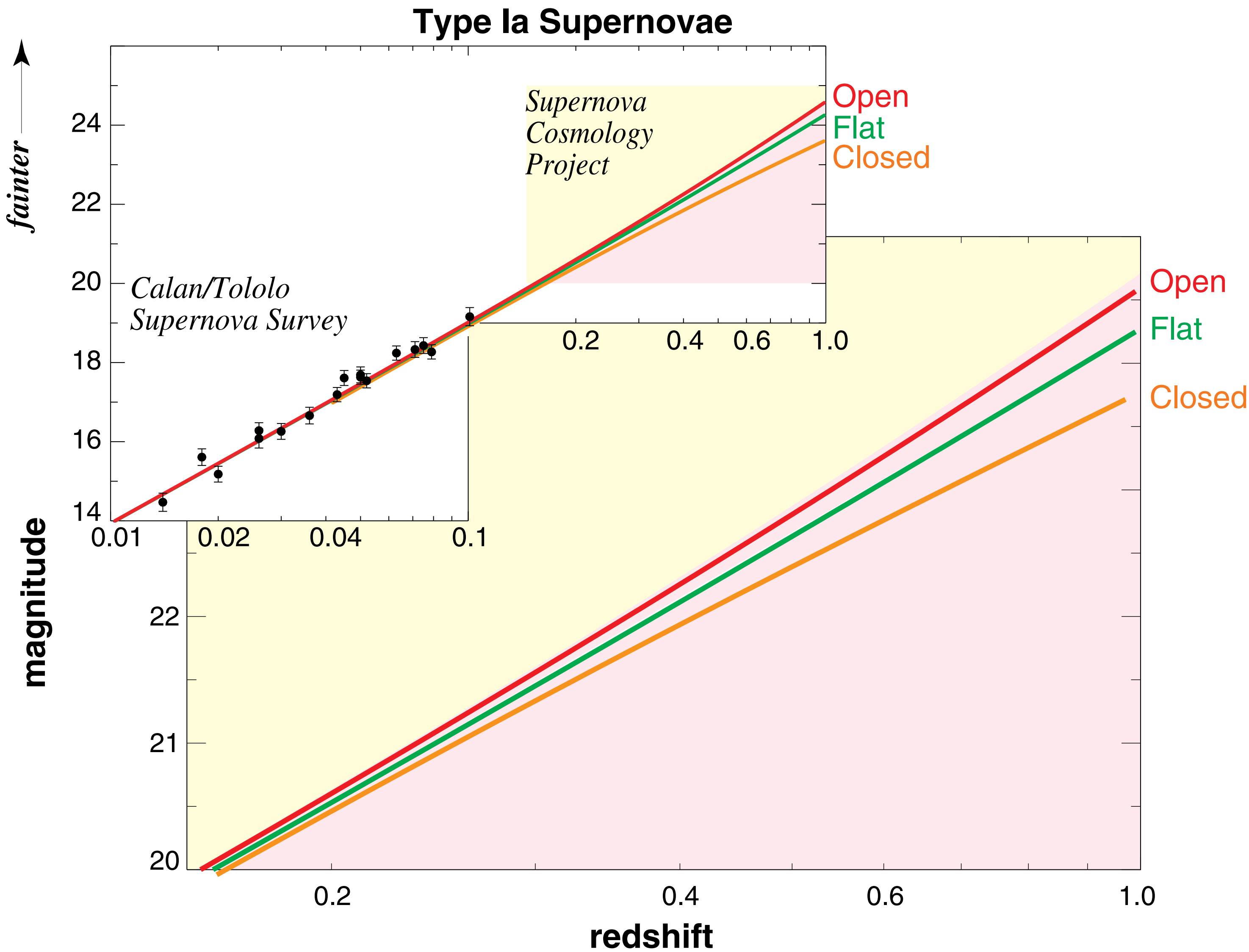
Unknown Component, Ω_u, of Energy Density



SNAP SuperNova Acceleration Probe

1. Irreducible Goal : $w'(z)$

A measurement of the expansion history of the universe with enough accuracy that a measurement of a *change* in the properties of the dark energy, e.g. $w' \neq 0$, would be trusted.



Type Ia Supernovae
fainter
magnitude
redshift
Calan/Tololo
Supernova Survey
Supernova
Cosmology
Project
Open
Flat
Closed
24
22
20
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1.0
22
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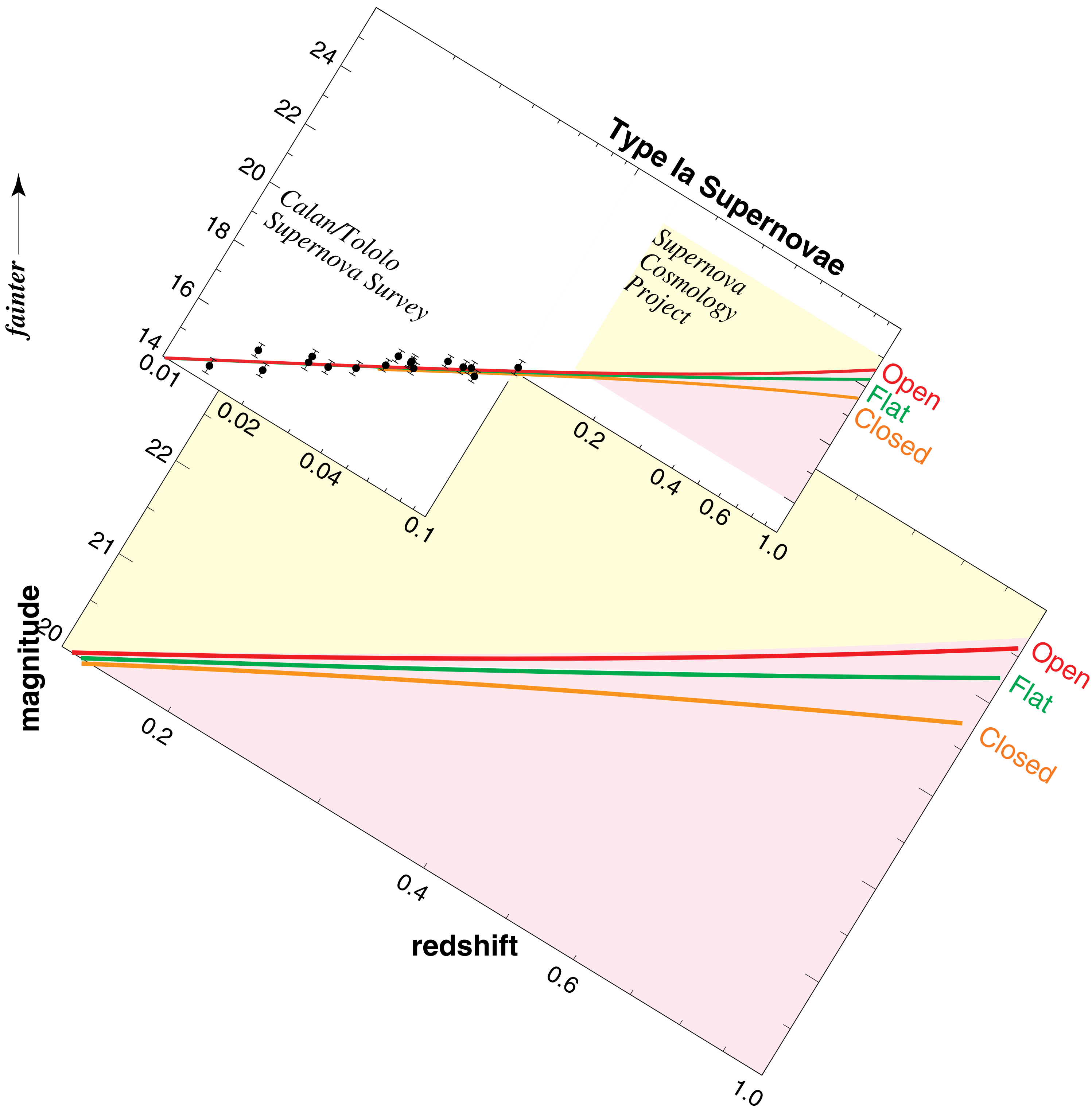
20



Type Ia Supernovae
Calan/Tololo Supernova Survey
Supernova Cosmology Project
Open
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14
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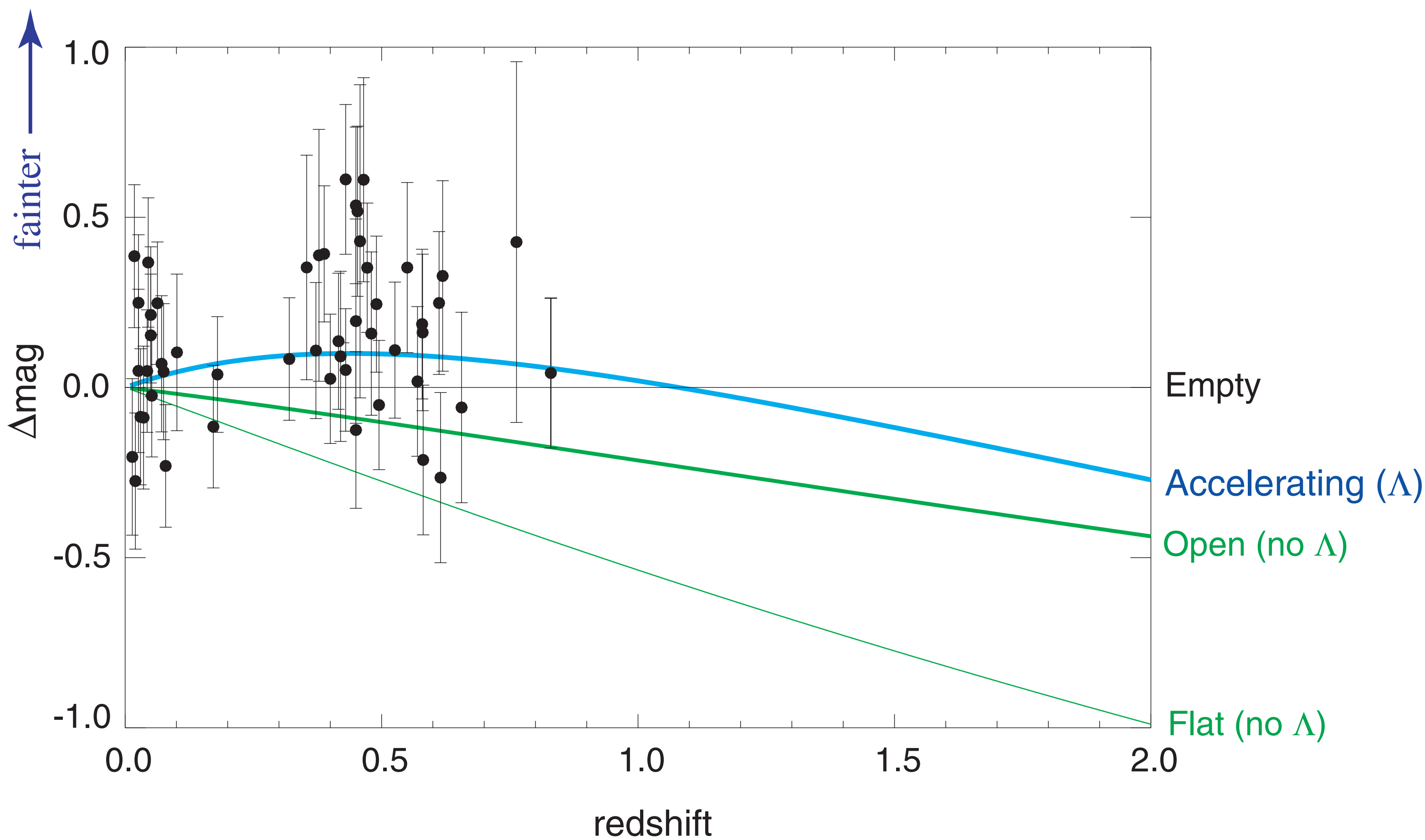
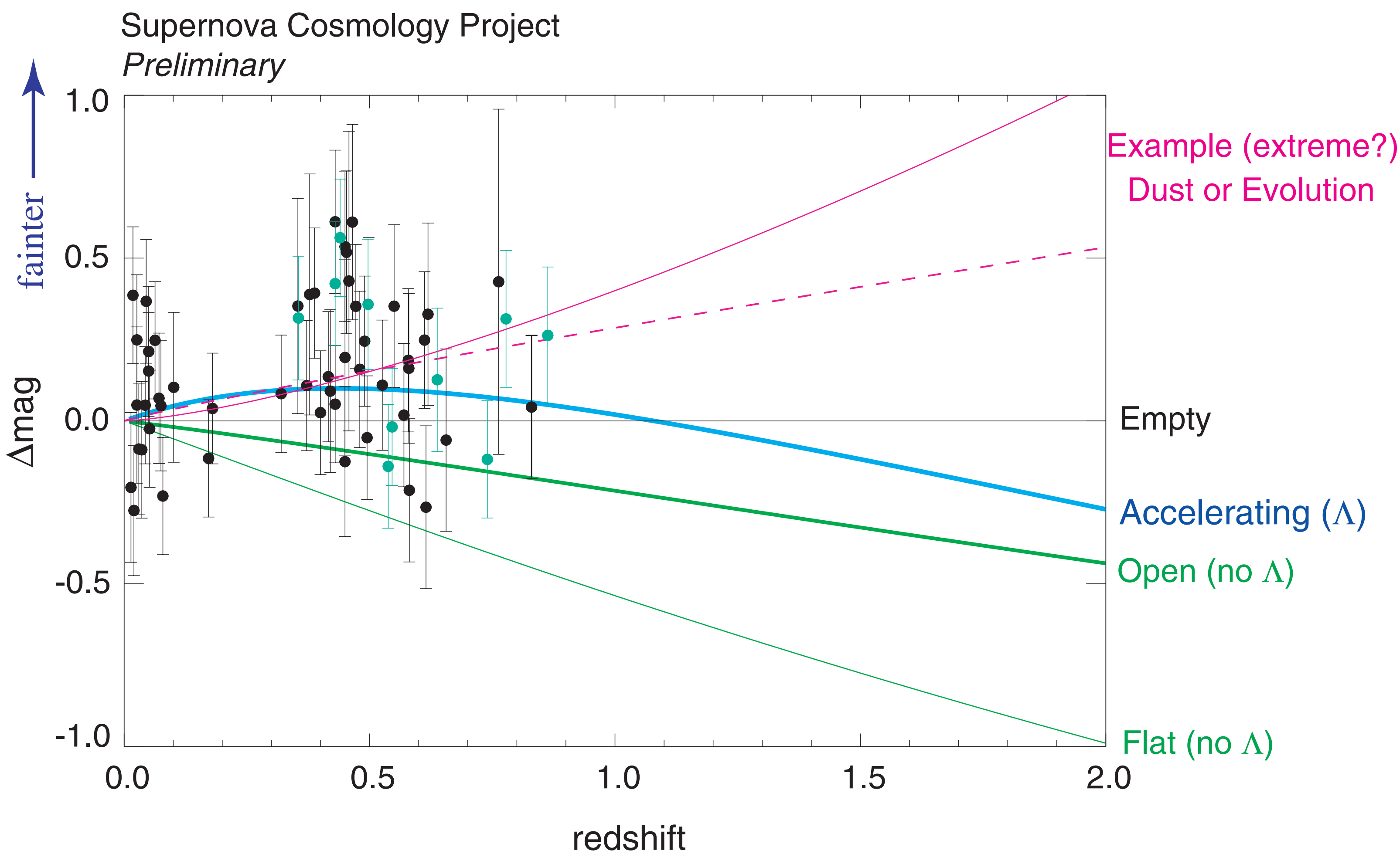
0.4
0.6
1.0
20
21
22
0.2
0.4
0.6
1.0
Open
Flat
Closed

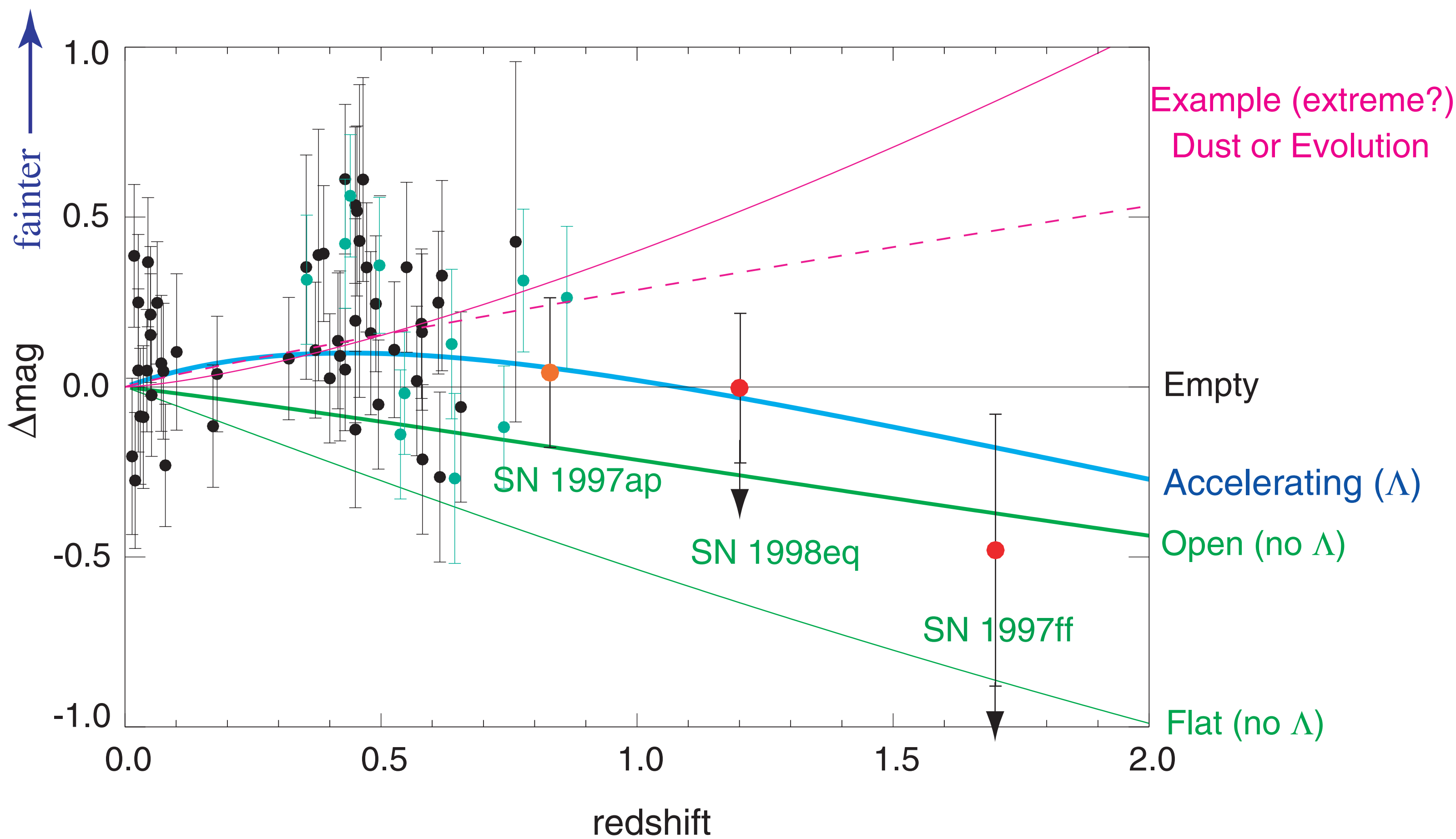
1998: Acceleration

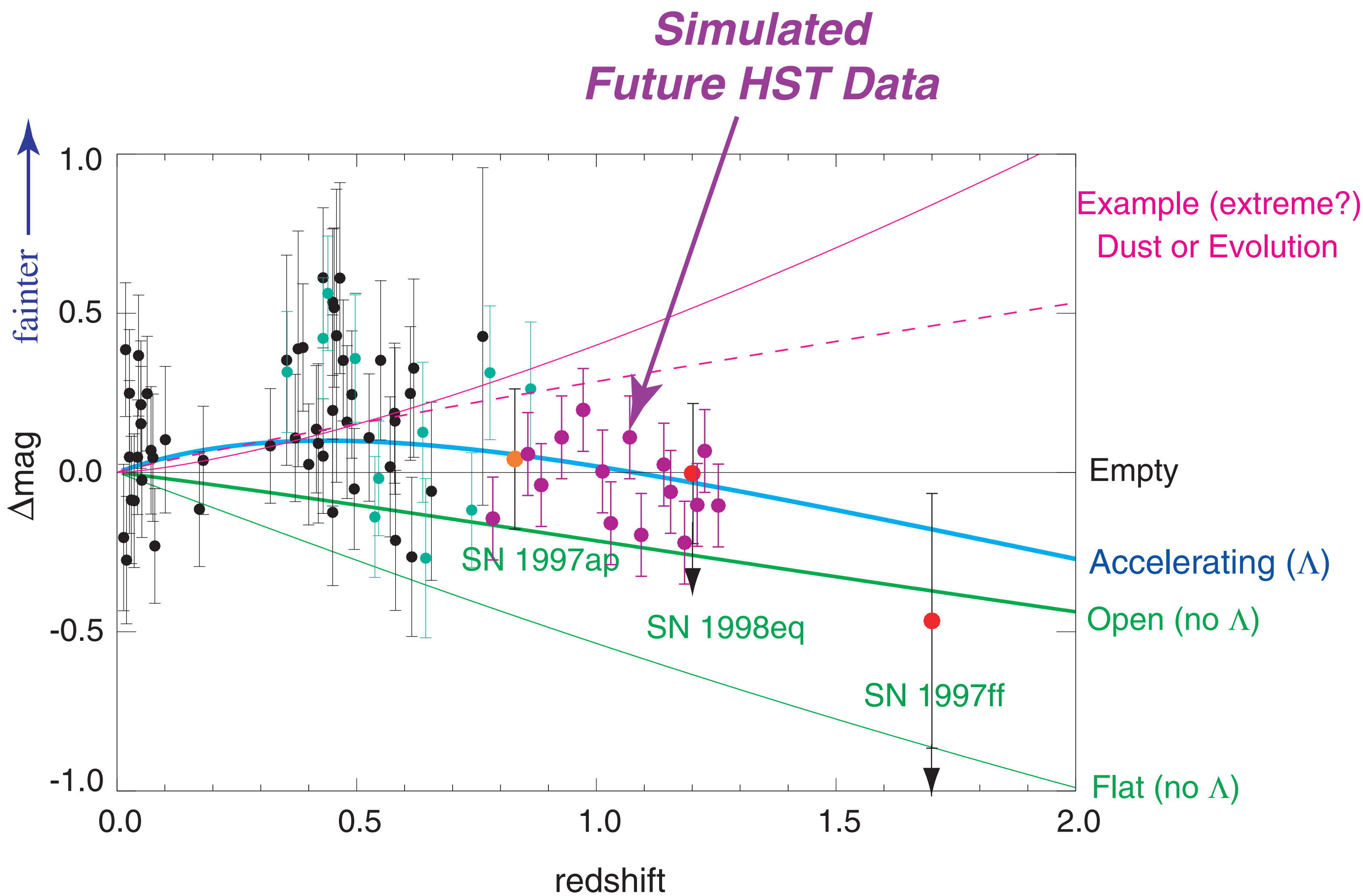


New HST data

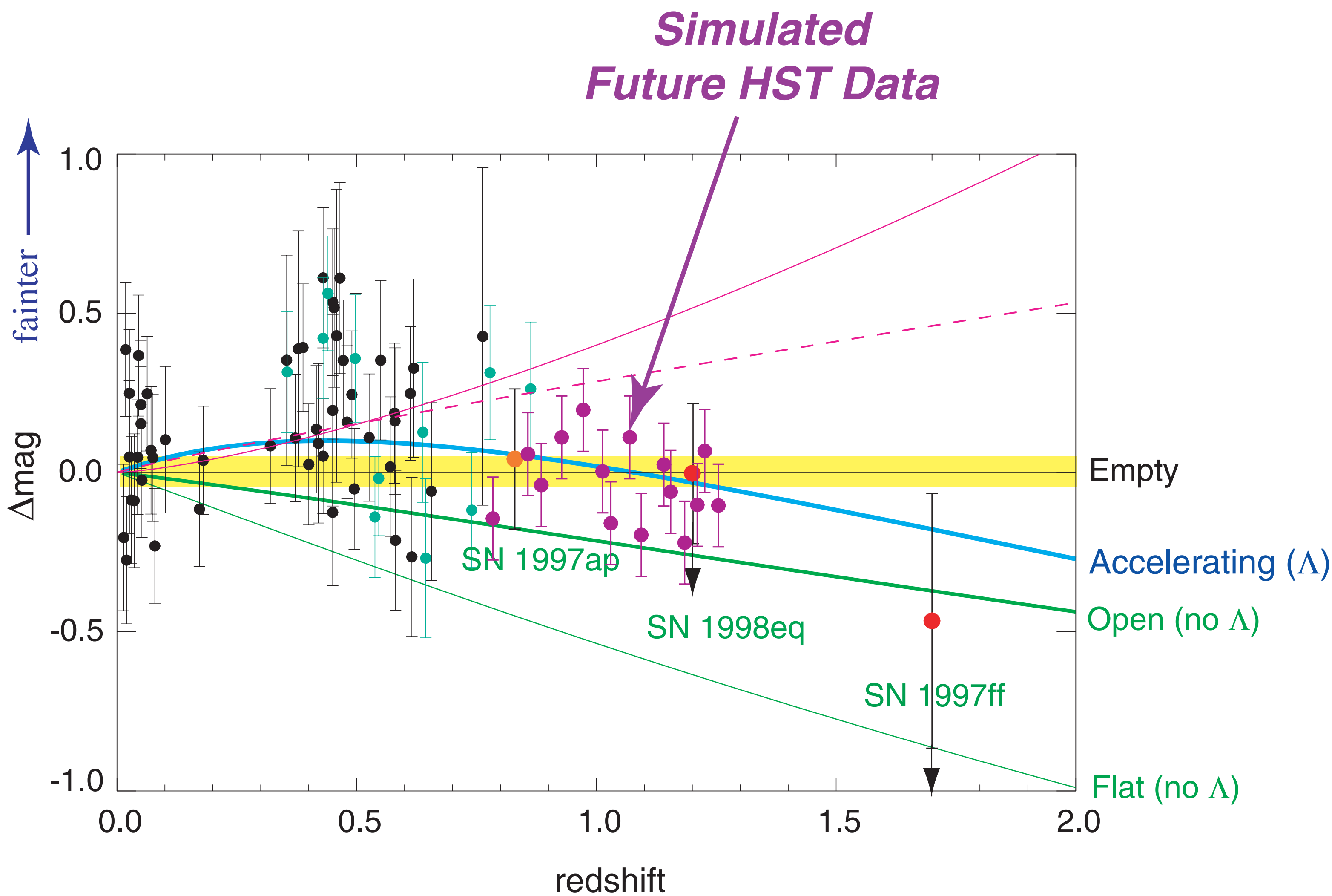

Supernova Cosmology Project
Preliminary
fainter
Δmag
1.0
0.5
0.0
-0.5
-1.0
0.0
0.5
1.0
1.5
2.0
redshift
Example (extreme?)
Dust or Evolution
Empty
Accelerating (Λ)
Open (no Λ)
Flat (no Λ)

Supernovae probing the *deceleration* era with IR measurements





Simulated
Future HST Data
fainter
Δmag
1.0
0.5
0.0
-0.5
-1.0
Example (extreme?)
Dust or Evolution
Empty
Accelerating (Λ)
Open (no Λ)
Flat (no Λ)
SN 1997ap
SN 1998eq
SN 1997ff
0.0
0.5
1.0
1.5
2.0
redshift



Simulated
Future HST Data
fainter
Δmag
1.0
0.5
0.0
-0.5
-1.0
0.0
0.5
1.0
1.5
2.0
redshift
Empty
Accelerating (Λ)
Open (no Λ)
Flat (no Λ)
SN 1997ap
SN 1998eq
SN 1997ff

Current statistical uncertainties from supernova measurements are almost good enough that they are limited by systematic uncertainties:

Uncertainties on Ω_M or Ω_Λ in flat cosmology:

Statistical	
high-redshift SNe	0.05
low-redshift SNe	0.065
Total	***0.085***
Systematic Total	
identified entities/processes	***0.05***

Significant advances in these measurement uncertainties will require **much better constraints on the systematics.**

Perlmutter et al. (1999)

What makes the supernova measurement special?

An exhautive accounting of sources of SN systematic uncertainties:

SN Ia Evolution

- o shifting distribution of
  progenitor mass/metallicity/C-O
- o shifting distibution of SN physics params:
  - -- amount of Nickel fused in explosion
  - -- distribution of Nickel
  - -- kinetic energy of explosion
  - -- opacity of atmosphere's inner layers
  - -- metallicity

Gravitational Lensing (de)amplification

Dust/Extinction

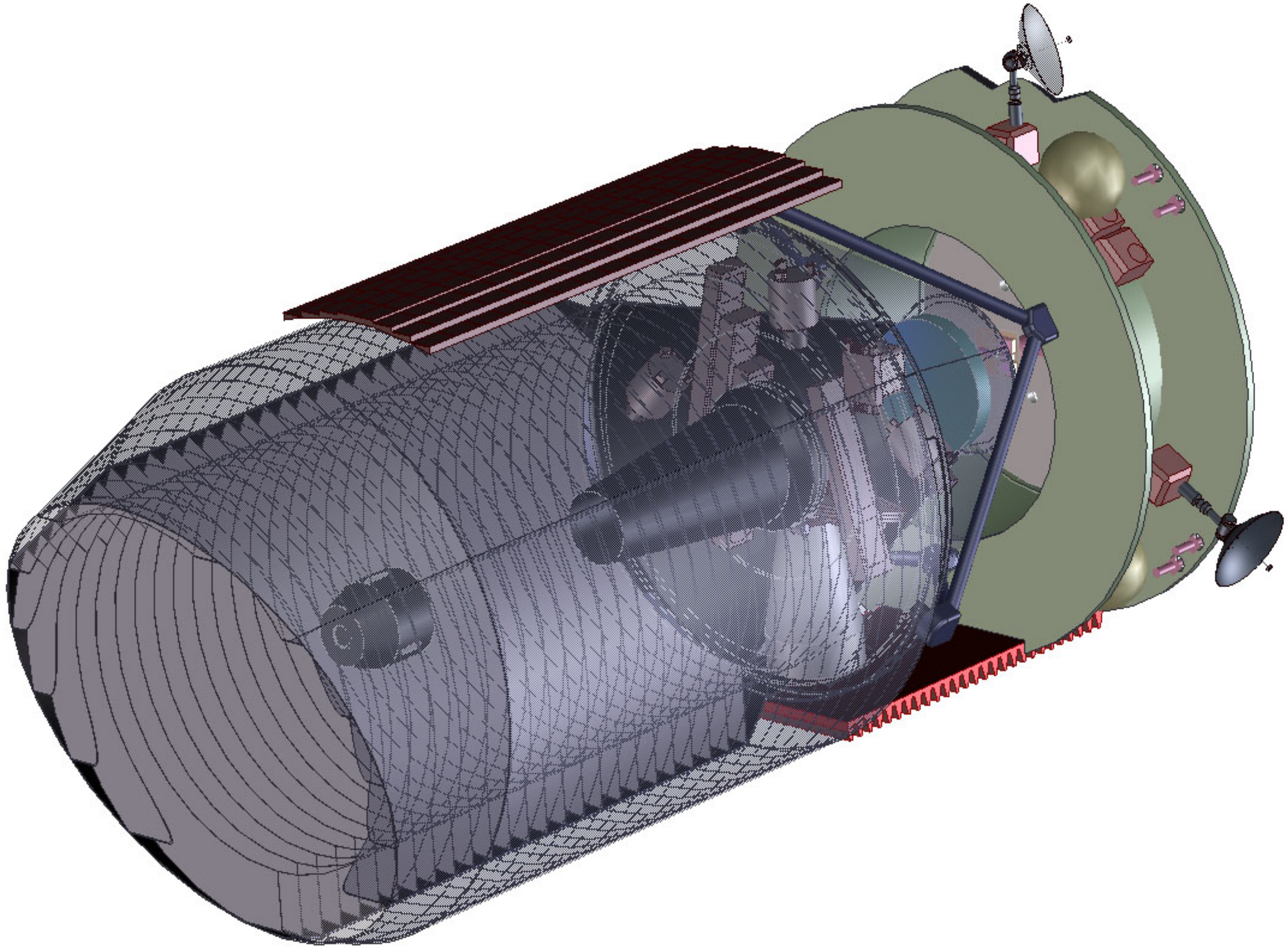
- o dust that reddens
- o evolving gray dust
  - -- clumpy
  - -- homogeneous
- o Galactic extinction model

Observational biases

- o Malmquist bias differences
- o non-SN Ia contamination
- o K-correction uncertainty
- o color zero-point calibration

Perlmutter et al. (1999)

SNAP SuperNova Acceleration Probe



- **~2 m aperture telescope**

  Can reach very distant SNe.

- **1 square degree mosaic camera, 1 billion pixels**

  Efficiently studies large numbers of SNe.

- **0.35um -- 1.7um spectrograph**

  Detailed analysis of each SN.

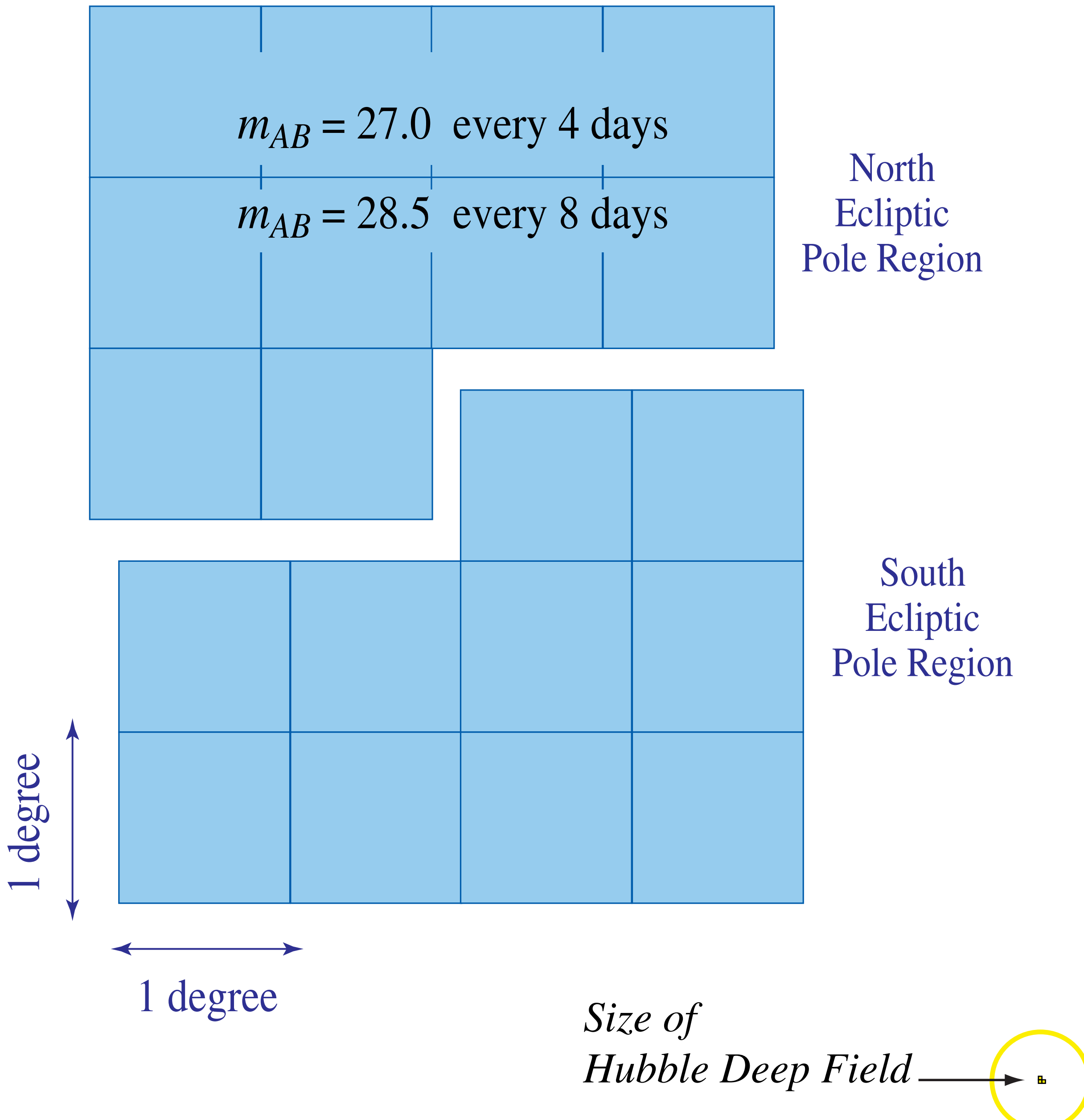
Dedicated instrument designed to repeatedly observe an area of sky.

Essentially no moving parts.

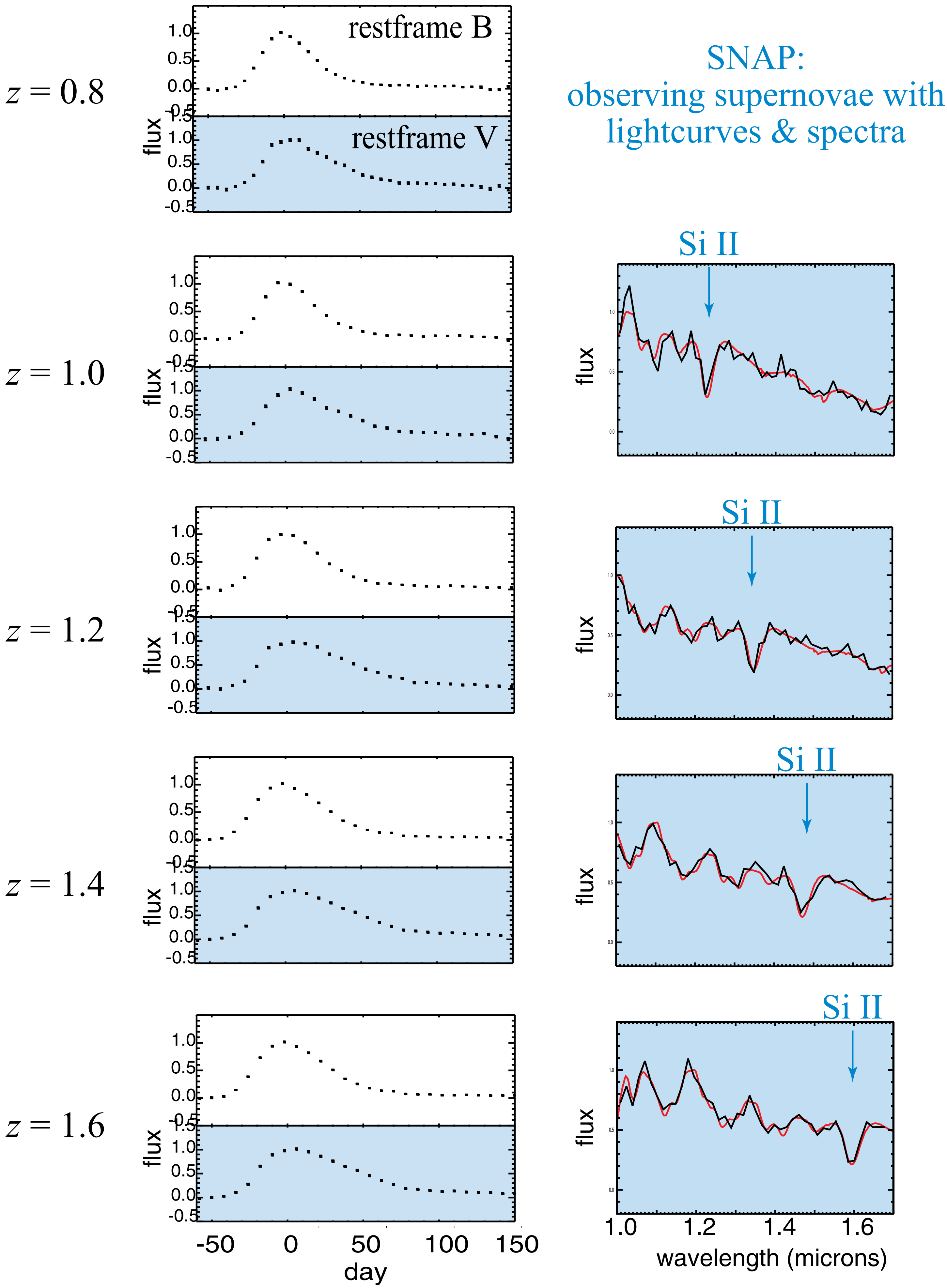
3-year operation for experiment (lifetime open-ended).

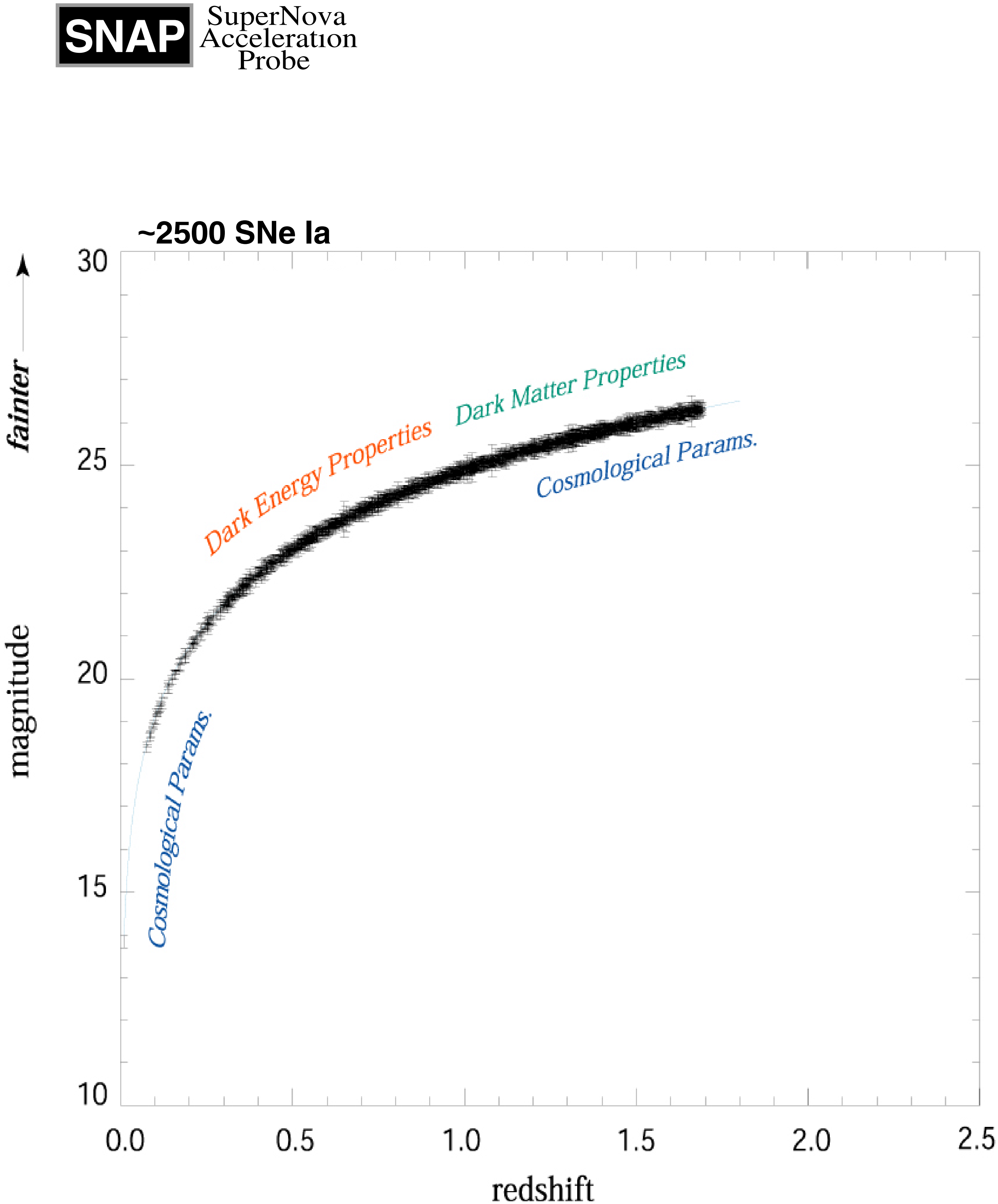
SNAP SuperNova Acceleration Probe

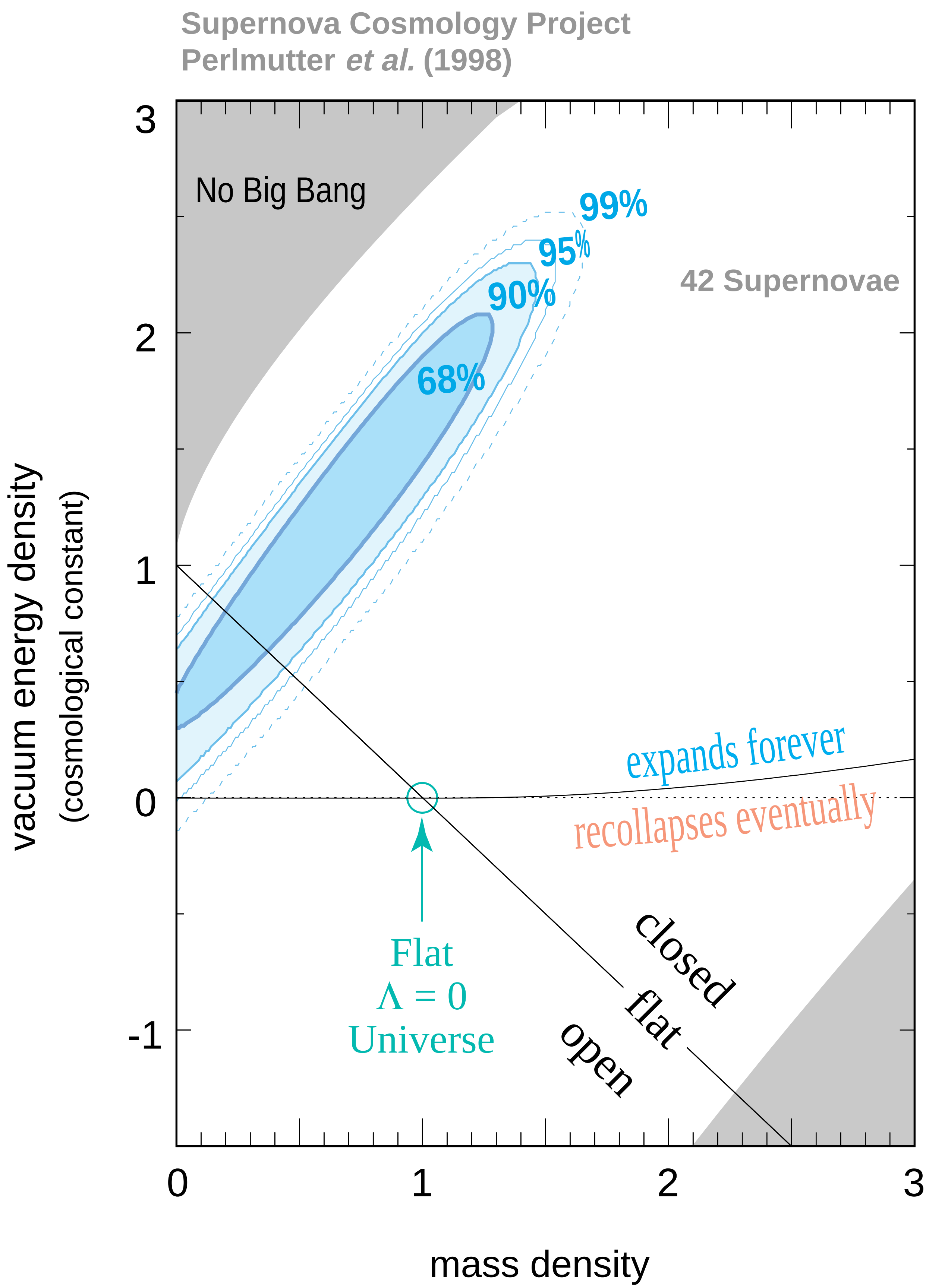
Survey scale

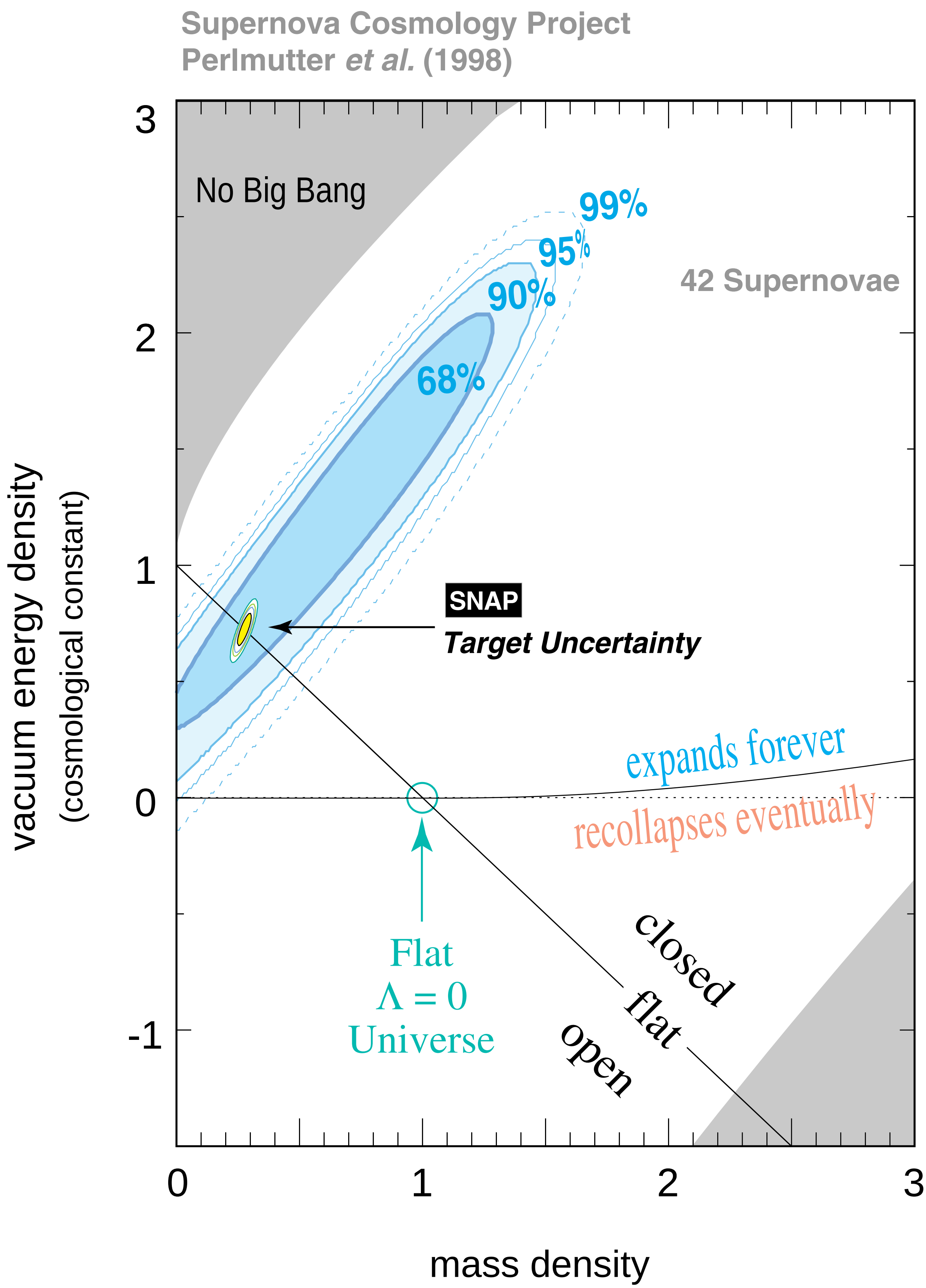


Co-added images: $\boldsymbol{m_{AB}} = 32.0$!


SNAP:
observing supernovae with
lightcurves & spectra
z = 0.8
z = 1.0
z = 1.2
z = 1.4
z = 1.6
restframe B
restframe V
flux
day
Si II
wavelength (microns)
-50
0
50
100
150
1.0
1.2
1.4
1.6
1.0
0.5
0.0
-0.5


SNAP
SuperNova
Acceleration
Probe
~2500 SNe Ia
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
2.5
redshift


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
3
2
1
0
-1
0
1
2
3


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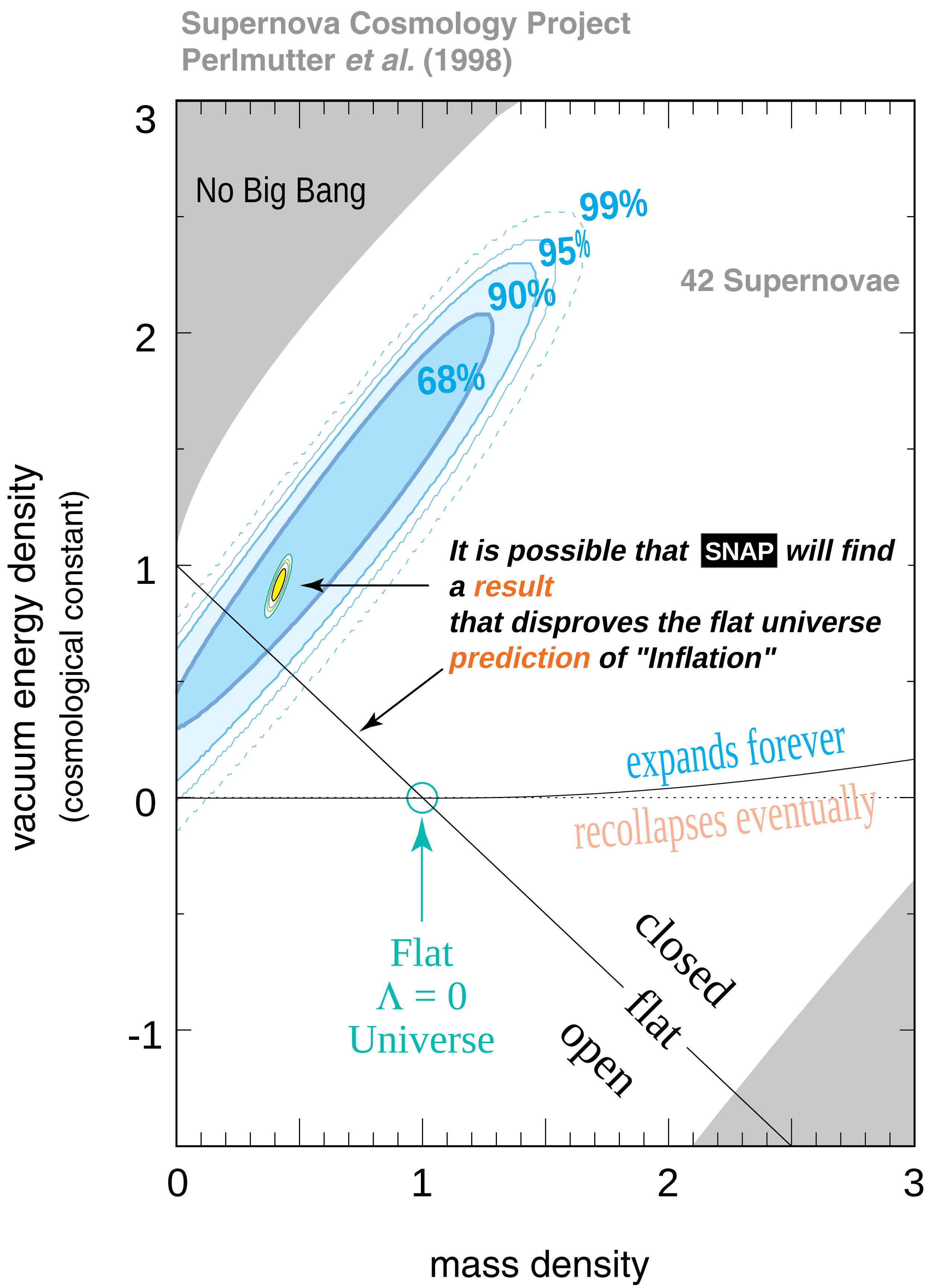
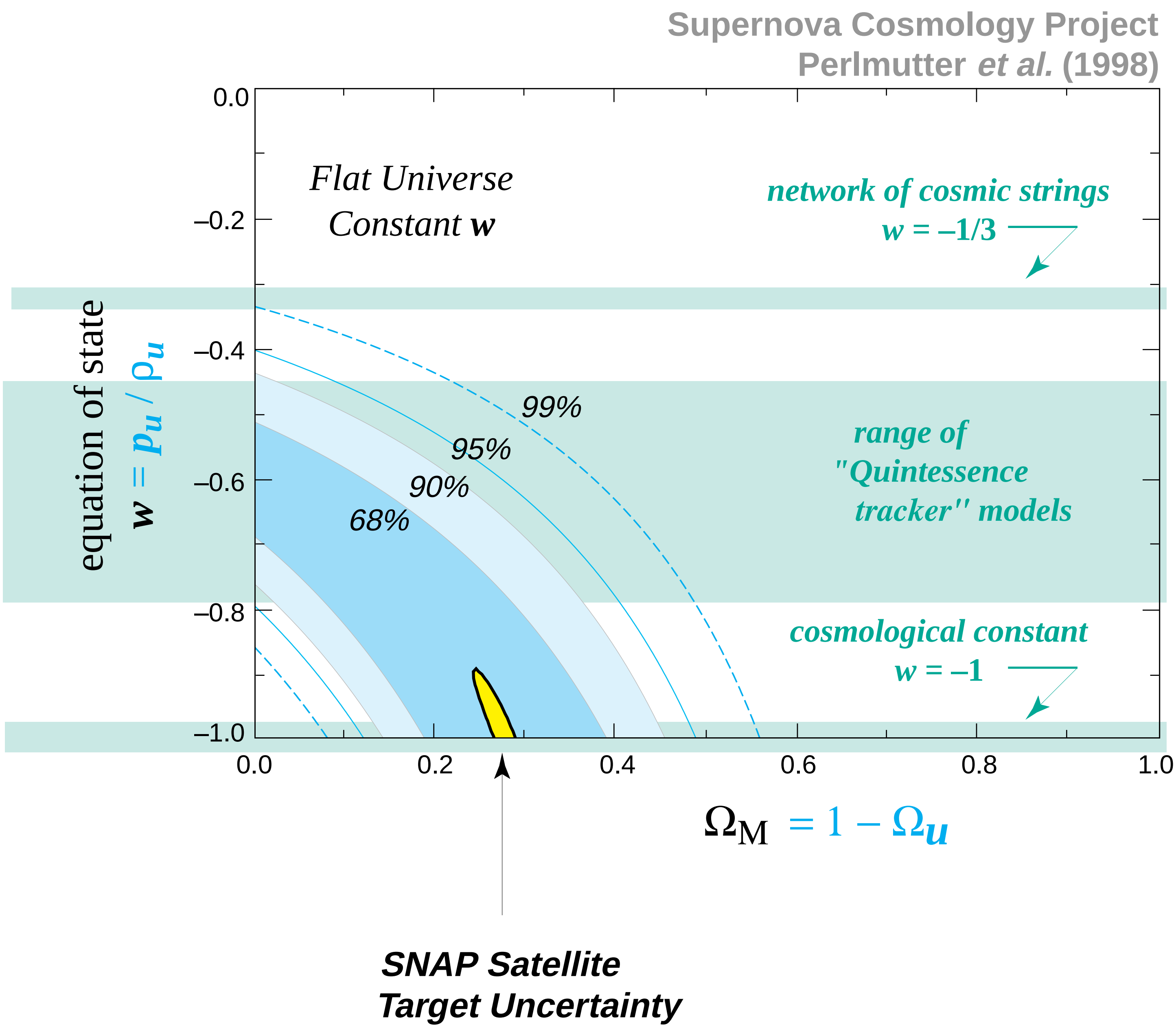
42 Supernovae
SNAP
Target Uncertainty
expands forever
recollapses eventually
closed
flat
open
Flat
Λ = 0
Universe
vacuum energy density
(cosmological constant)
mass density
3
2
1
0
-1
0
1
2
3



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
3
2
1
0
-1
0
1
2
3
vacuum energy density
(cosmological constant)
mass density

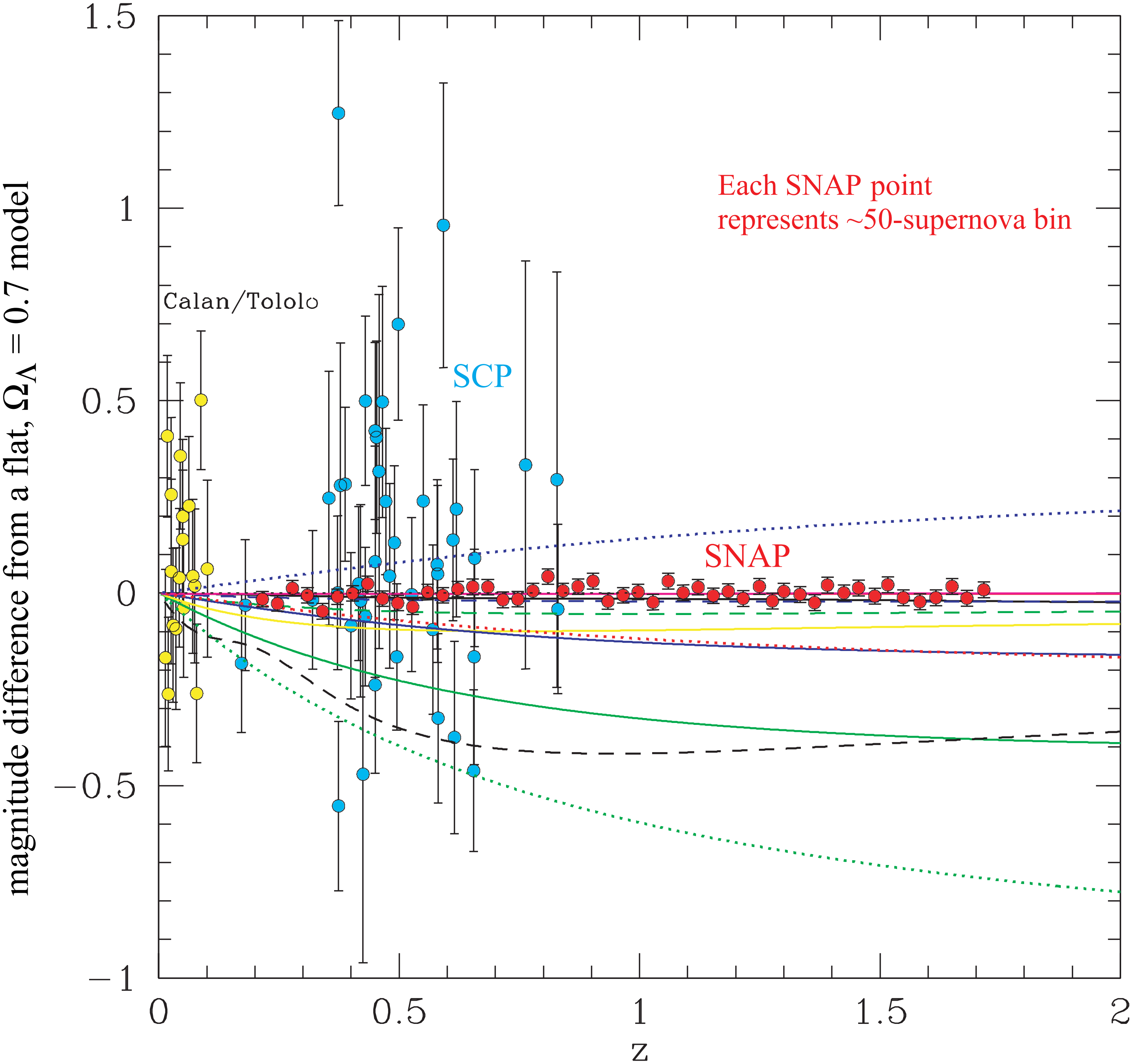
Dark Energy

Unknown Component, Ω_u, of Energy Density



SNAP SuperNova Acceleration Probe

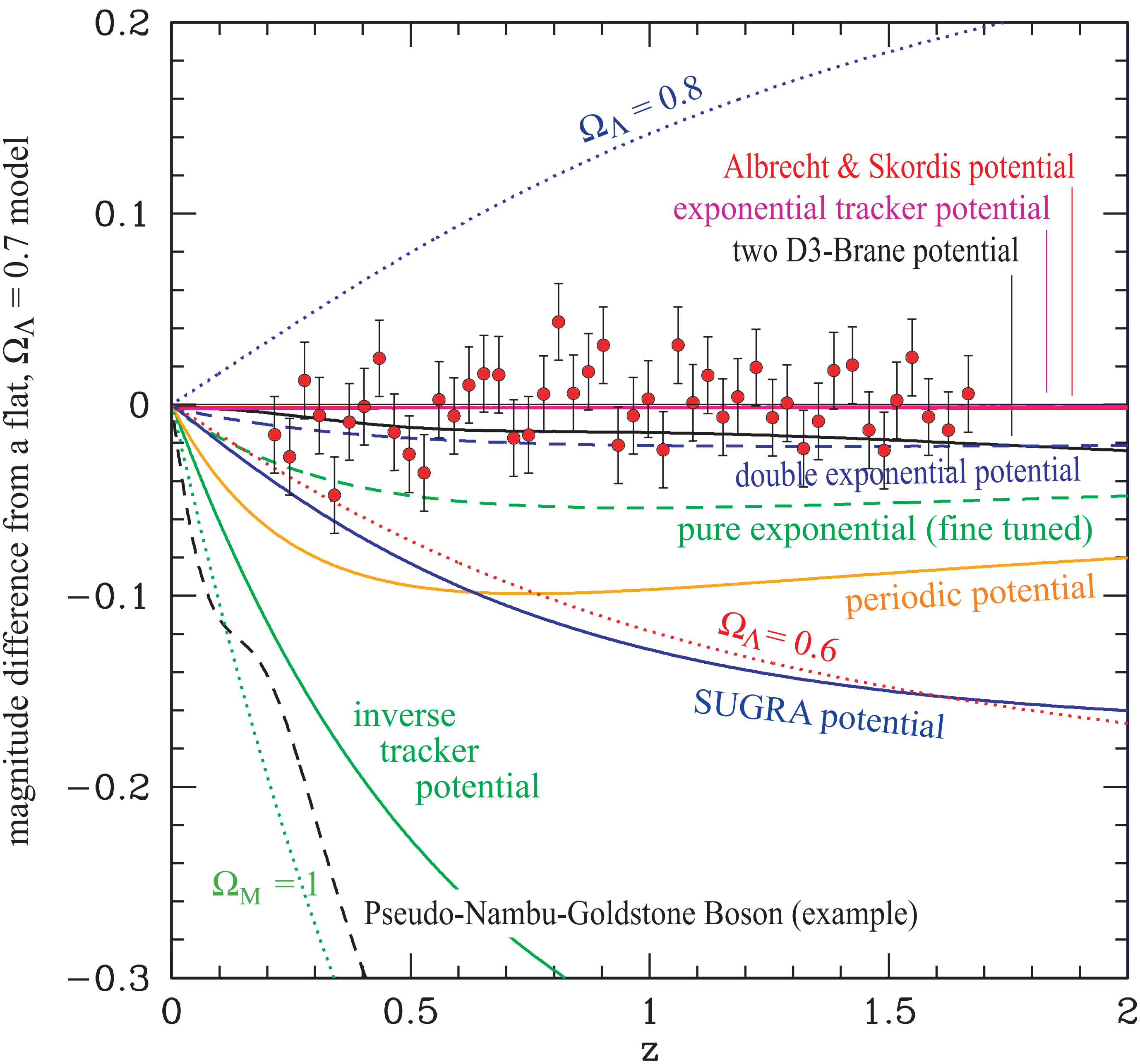
Current ground-based data compared with binned simulated SNAP data and a sample of Dark Energy models.



based on Weller & Albrecht (2001)

SNAP SuperNova Acceleration Probe

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



based on

Weller & Albrecht (2001)

SuperNova Acceleration Probe

Binned simulated SNAP data
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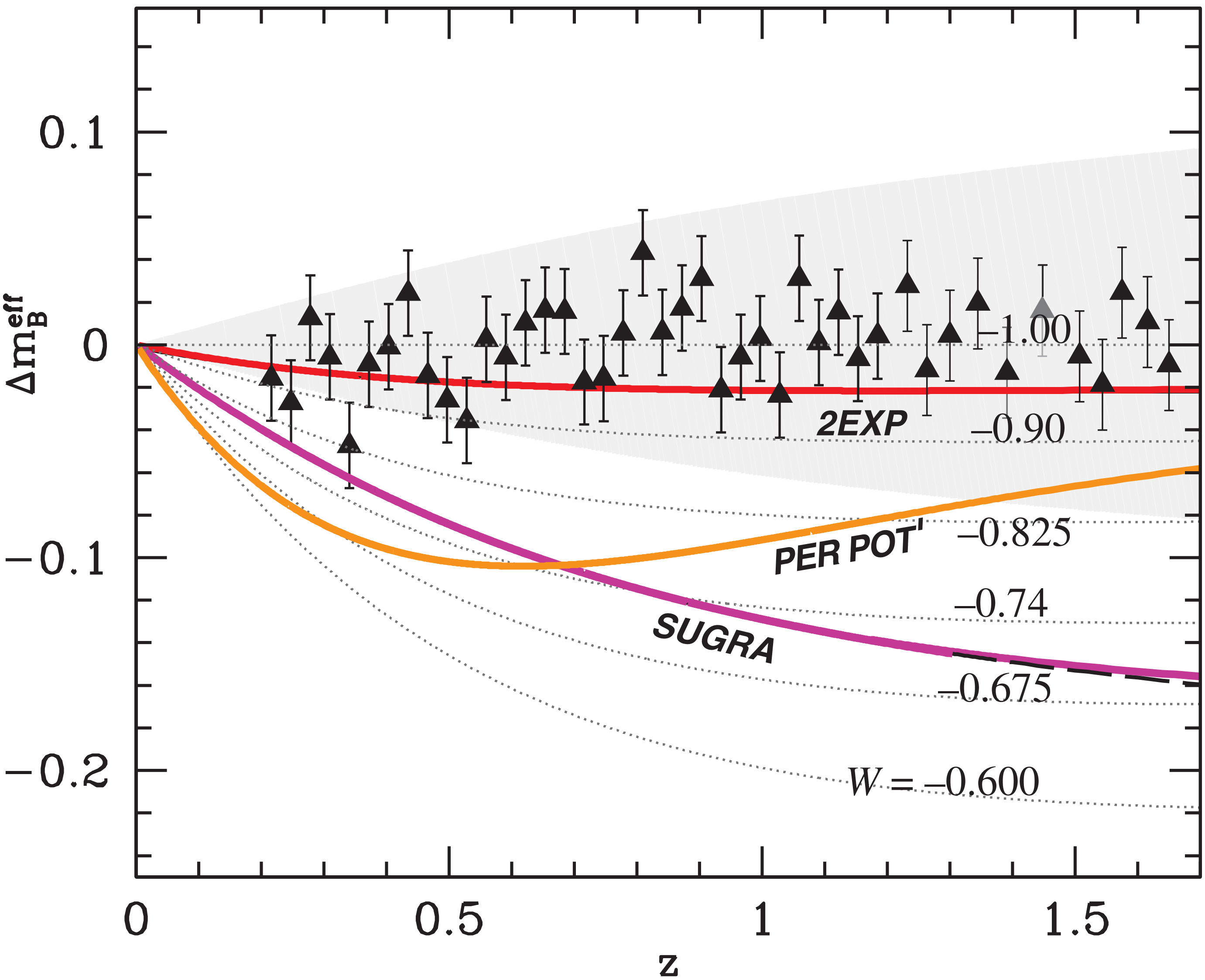

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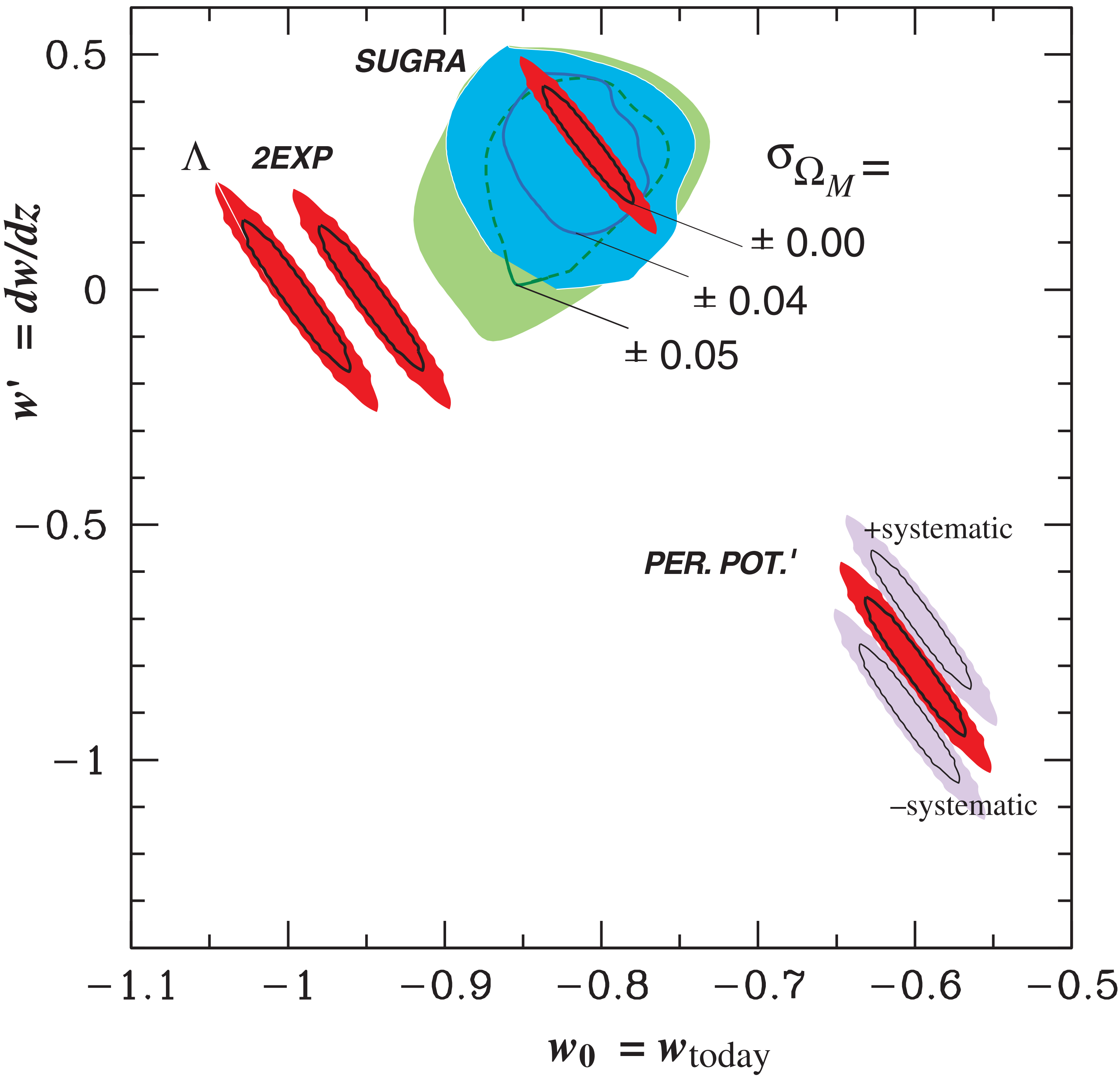


SNAP SuperNova Acceleration Probe

Primary Science Mission

Requiring complementary measurements of cosmological parameters, Dark Matter, Dark Energy,...

Type Ia supernova calibrated candle:
  Hubble diagram to $z = 1.7$

Type II supernova expanding photosphere:
  Hubble diagram to $z = 1$ and beyond.

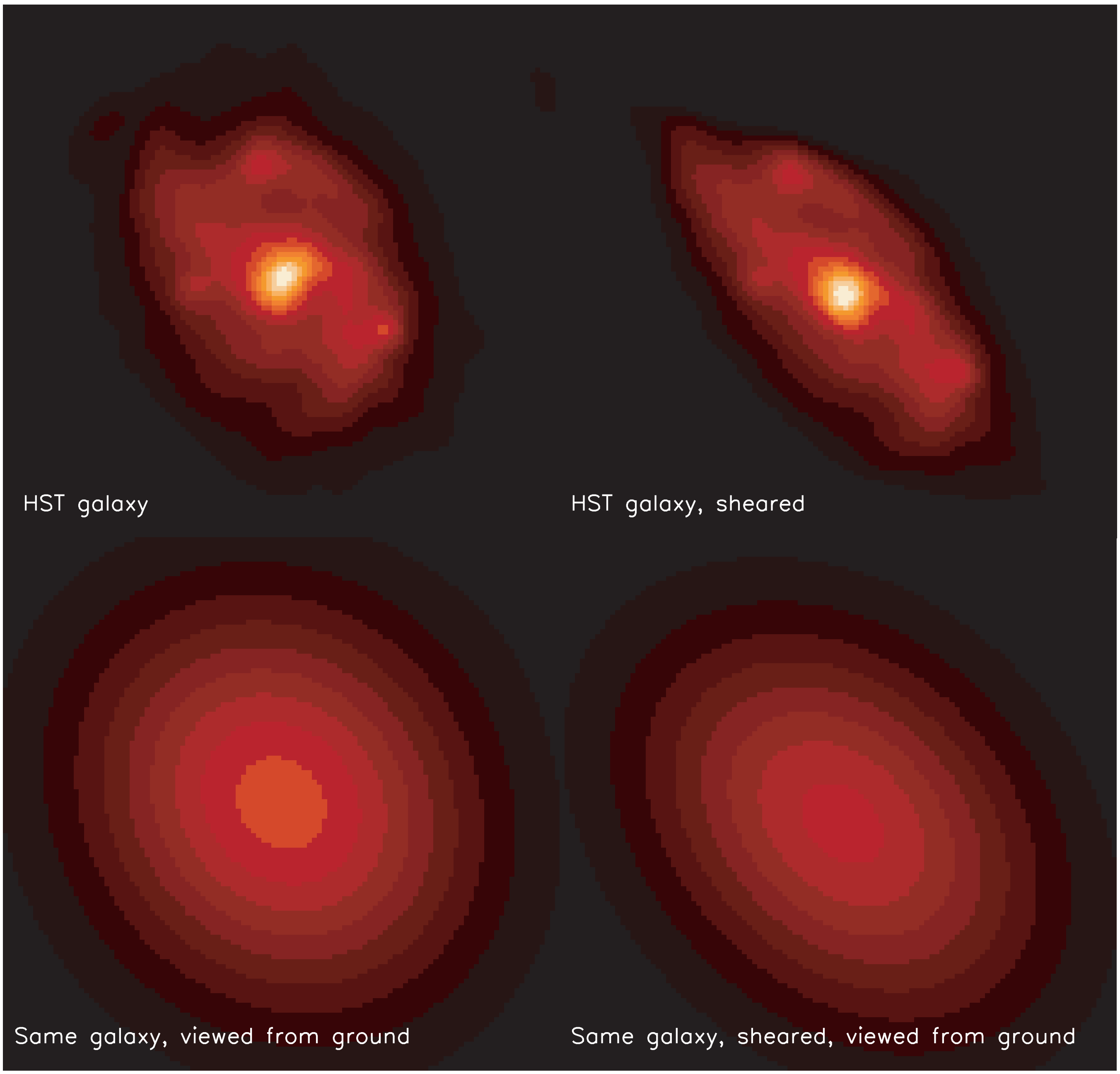
Weak lensing:
  Direct measurements of $P(k)$ vs z
  Mass selected cluster survey vs z

Strong lensing statistics: Ω_Λ
  10x gains over ground based optical resolution, IR channels + depth.

Galaxy clustering:
  $W(\Theta)$ angular correlation vs redshift from 0.5 to 3.0

SNAP SuperNova Acceleration Probe

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



(Bacon, Ellis, Refregier, Nov. 2000)

2. Why does this goal require SNAP?

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- o Malmquist bias differences
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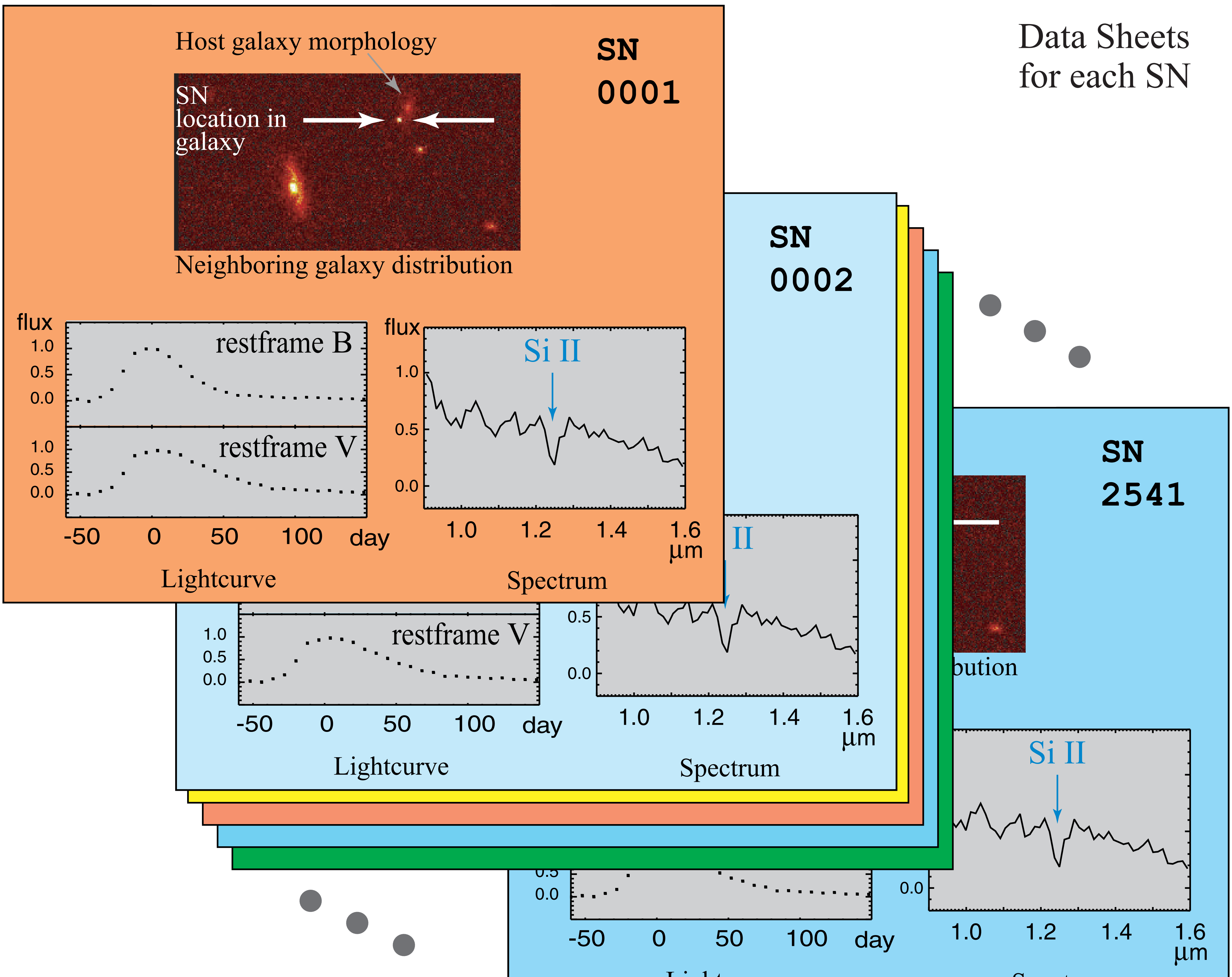
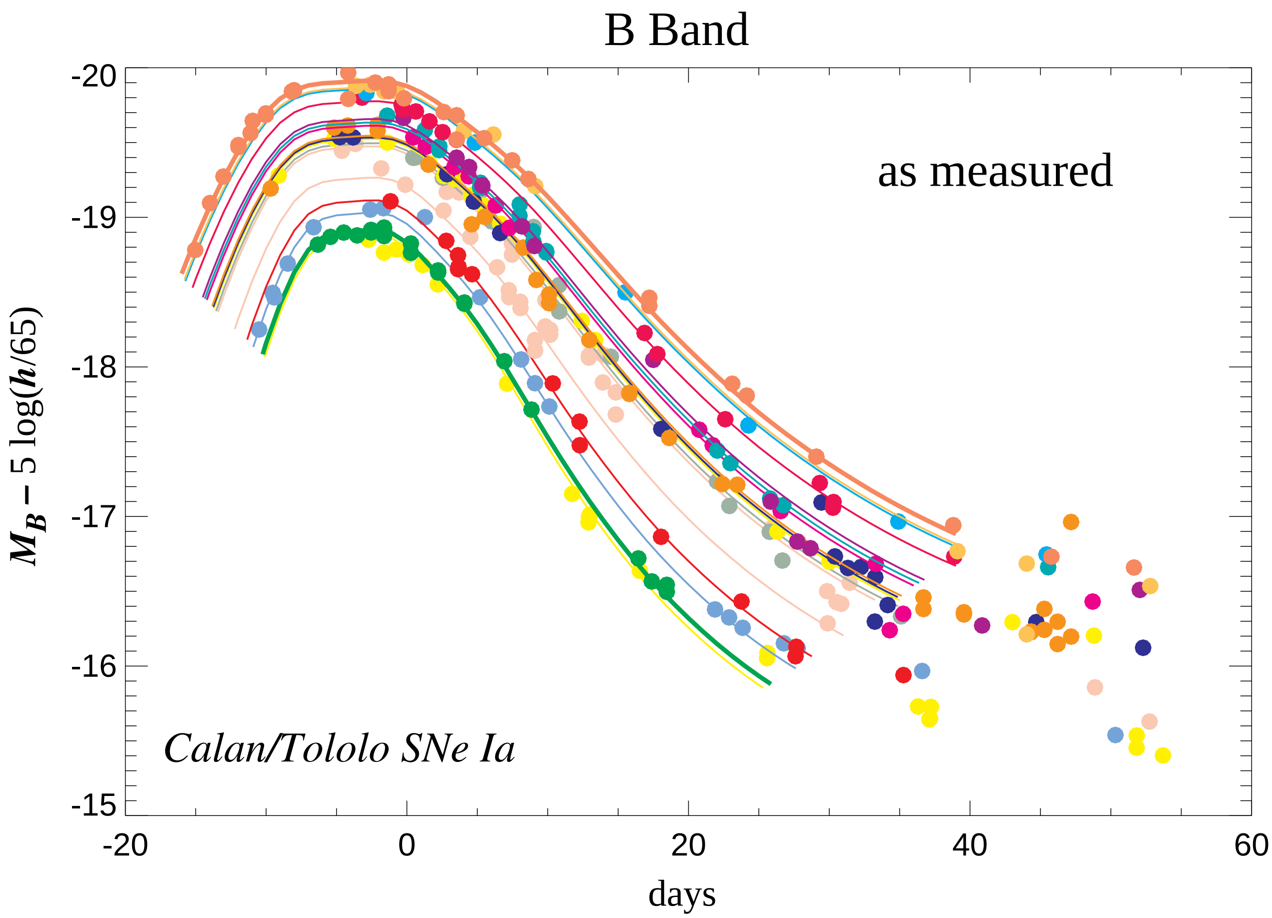
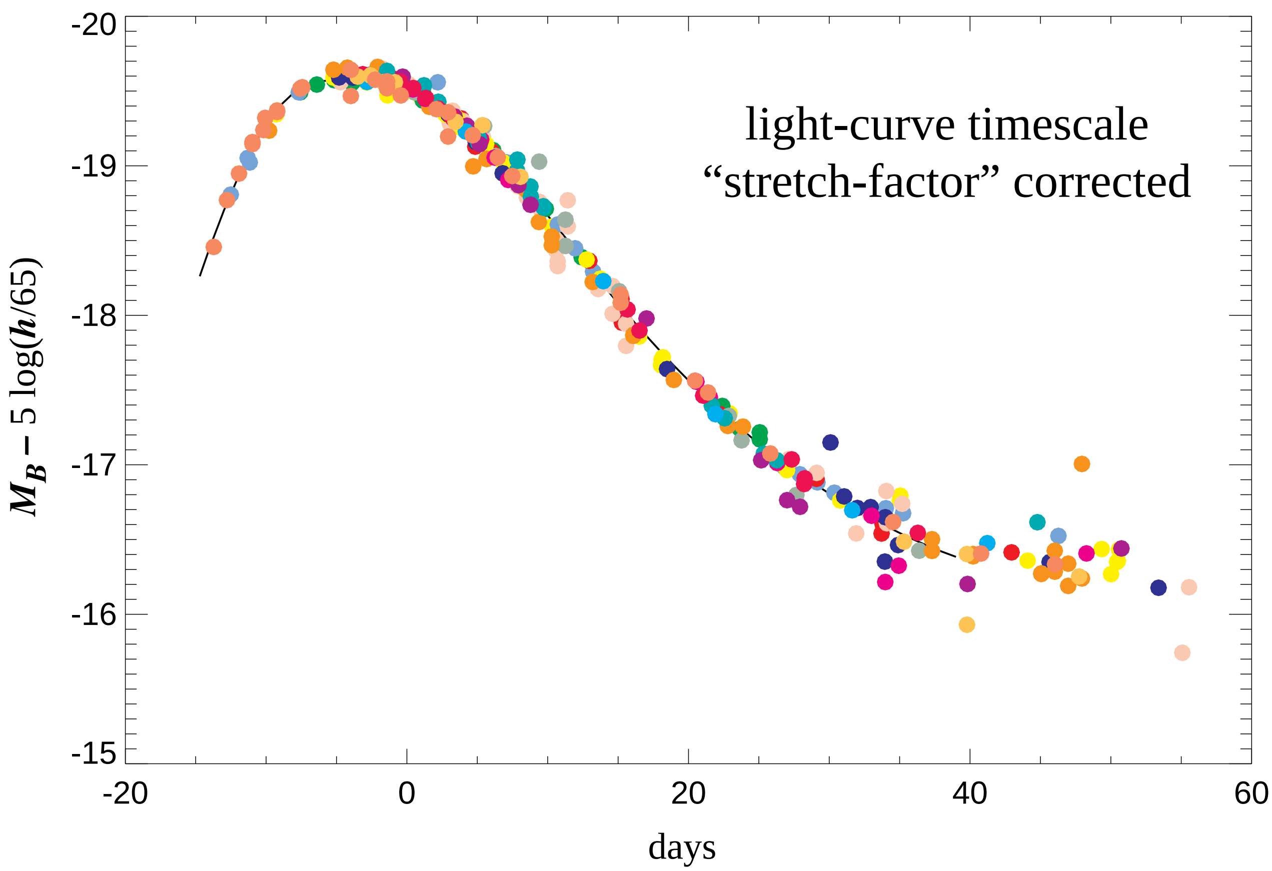
Perlmutter et al. (1999)



Data Sheets for each SN
SN 0001
Host galaxy morphology
SN location in galaxy
Neighboring galaxy distribution
flux
restframe B
restframe V
Lightcurve
day
Si II
Spectrum
µm
SN 0002
SN 2541

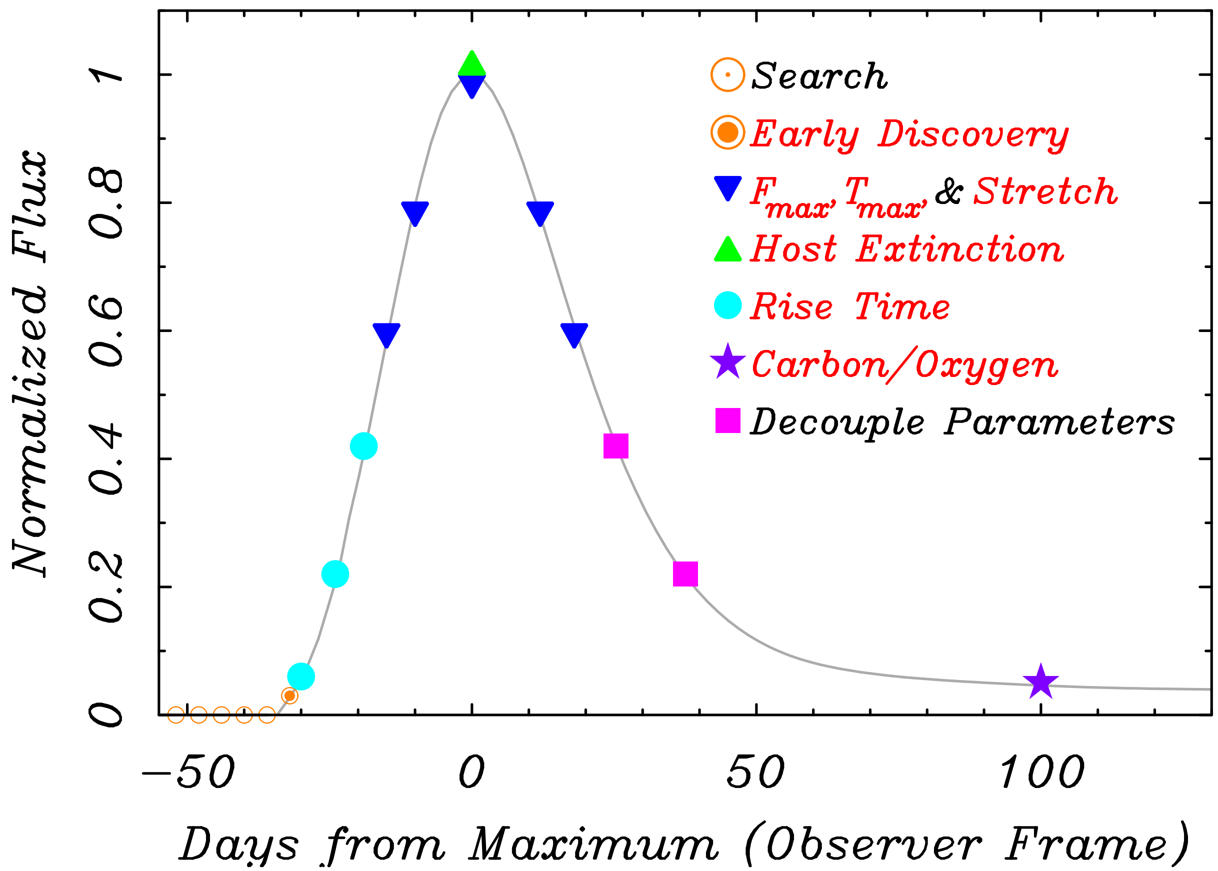


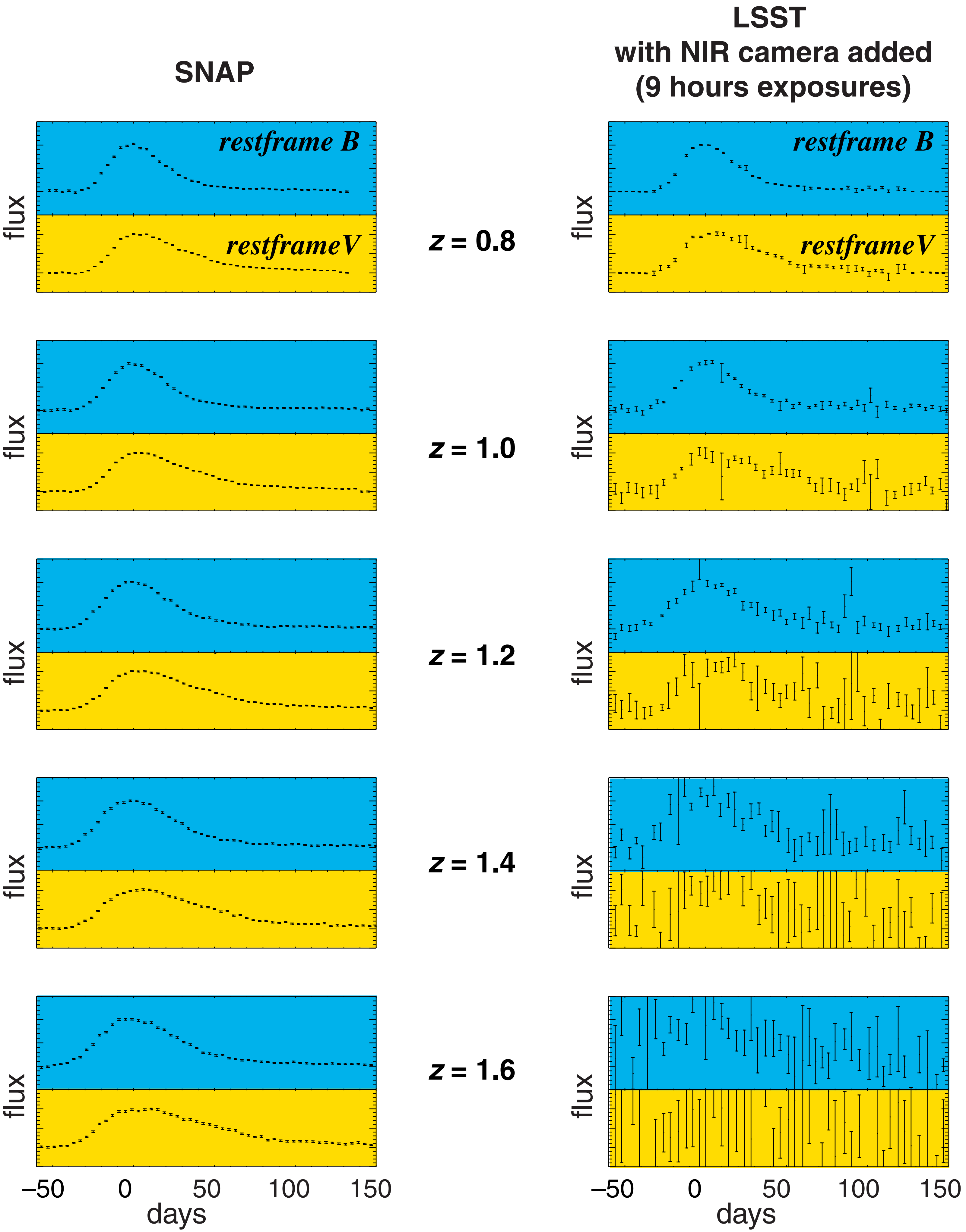


Kim, *et al.* (1997)

SNAP SuperNova Acceleration Probe

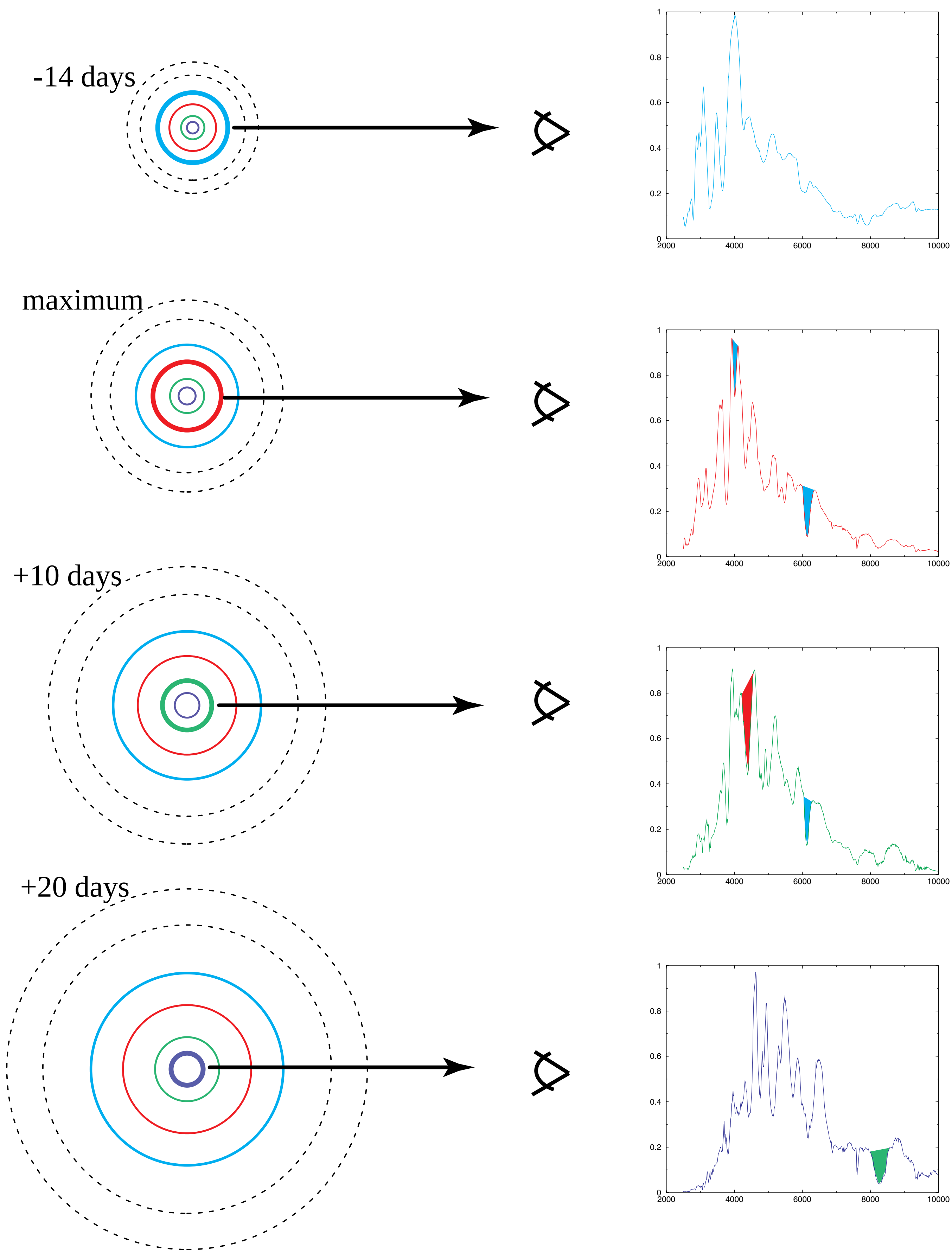
B−band Lightcurve Photometry for z = 0.8 Type Ia



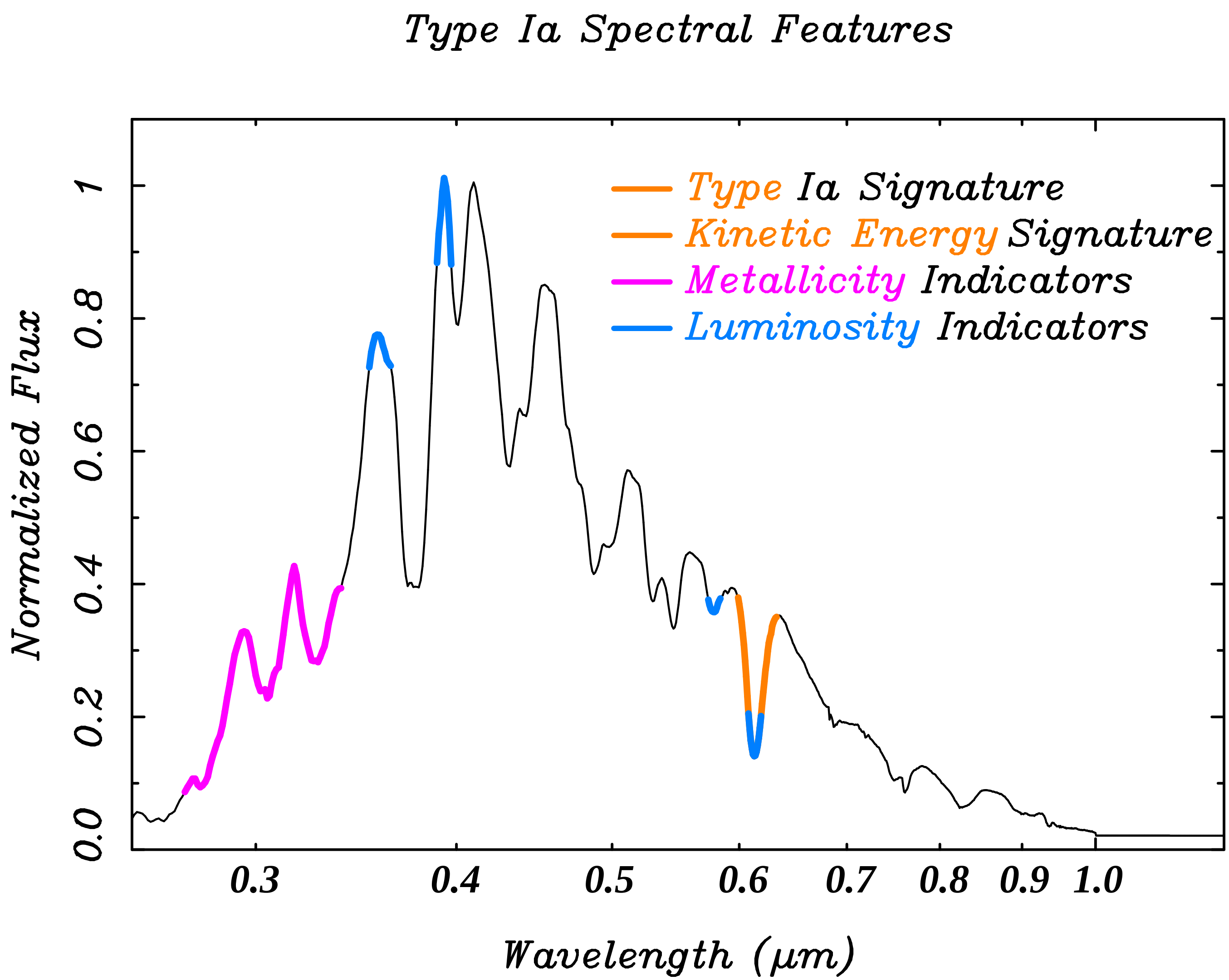


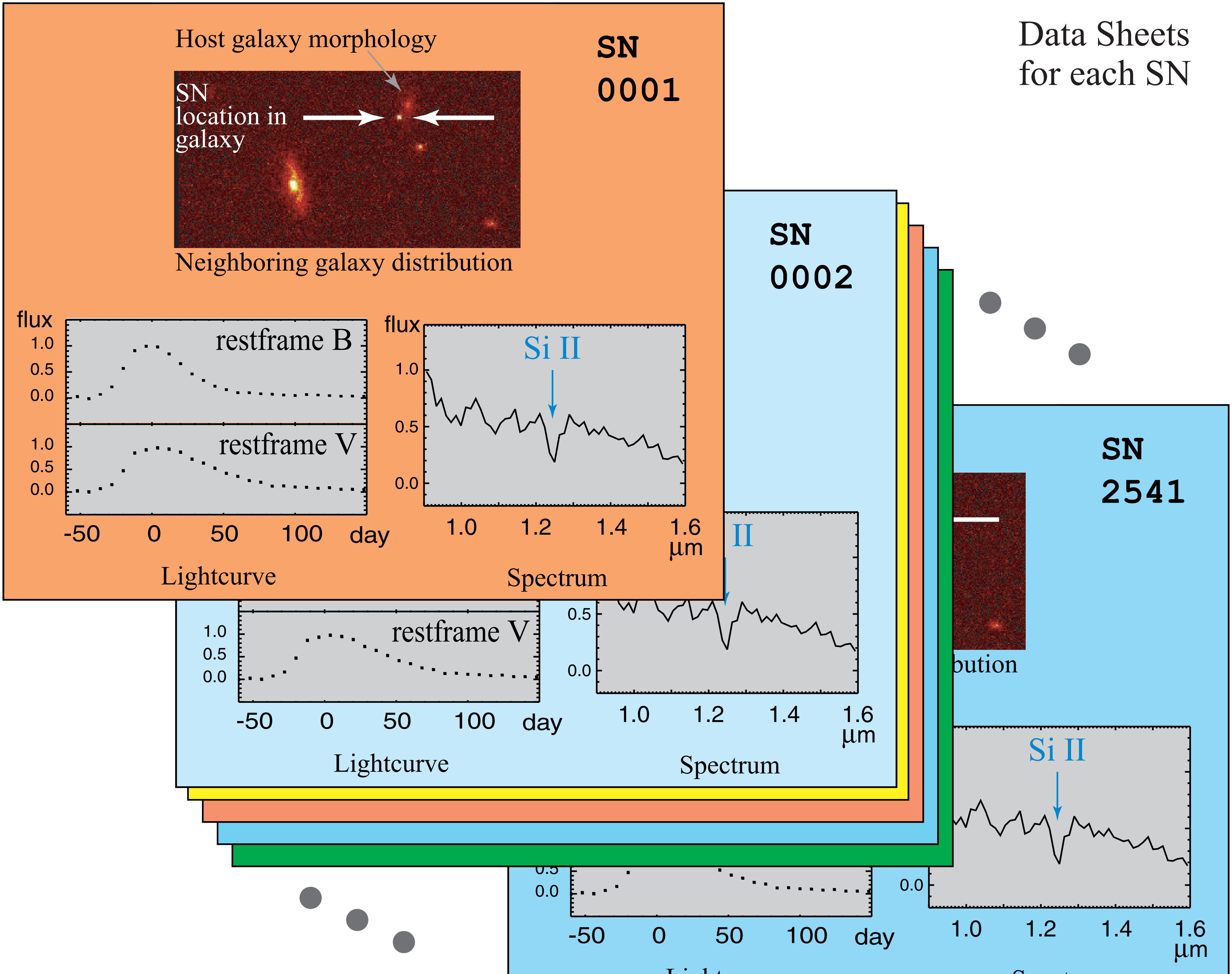
SNAP
LSST
with NIR camera added
(9 hours exposures)
restframe B
restframe V
flux
z = 0.8
z = 1.0
z = 1.2
z = 1.4
z = 1.6
–50
0
50
100
150
days

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



SNAP SuperNova Acceleration Probe




Data Sheets
for each SN
SN
0001
Host galaxy morphology
SN
location in
galaxy
Neighboring galaxy distribution
flux
1.0
0.5
0.0
restframe B
restframe V
-50
0
50
100
day
Lightcurve
flux
Si II
1.0
0.5
0.0
1.0
1.2
1.4
1.6
µm
Spectrum
SN
0002
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2541

1

Sort into Like Subsets

Group A:
* Si II in spectrum: type Ia
* elliptical host
* bright UV: low metallicity
* fast rise time: low Ni56 mass
* spectral feature velocities
  9000 < v < 10000 km/s

⋮

Group B:
* Si II in spectrum: type Ia
* in core of late-type spiral host
* faint UV: high metallicity
* fast rise time: low Ni56 mass
* spectral feature velocities
  9000 < v < 10000 km/s

⋮

Group C:
* Si II in spectrum: type Ia
* in outskirts of late-type spiral host
* bright UV: low metallicity
* long rise time: high Ni56 mass
* spectral feature velocities
  8000 < v < 9500 km/s

⋮

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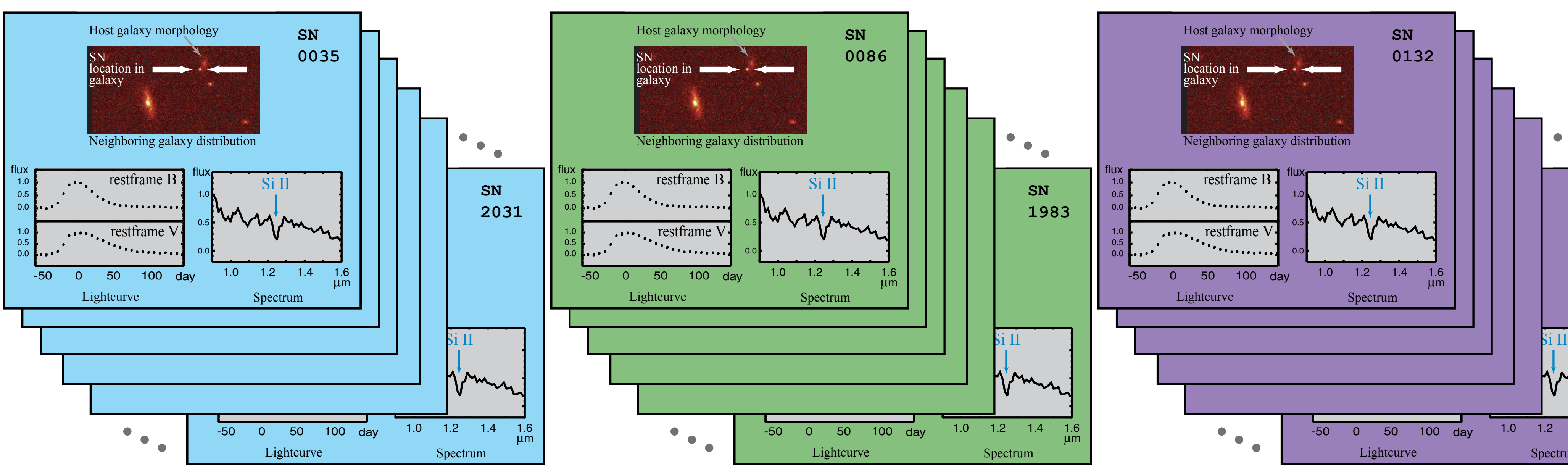
Gro
* Si II i
* in core
* brigh
* short
* spectr
  8000



2

Each subset gets its own extinction-corrected Hubble diagram:

Group A:
* Si II in spectrum: type Ia
* elliptical host
* bright UV: low metallicity
* fast rise time: low Ni56 mass
* spectral feature velocities 9000 < v < 10000 km/s

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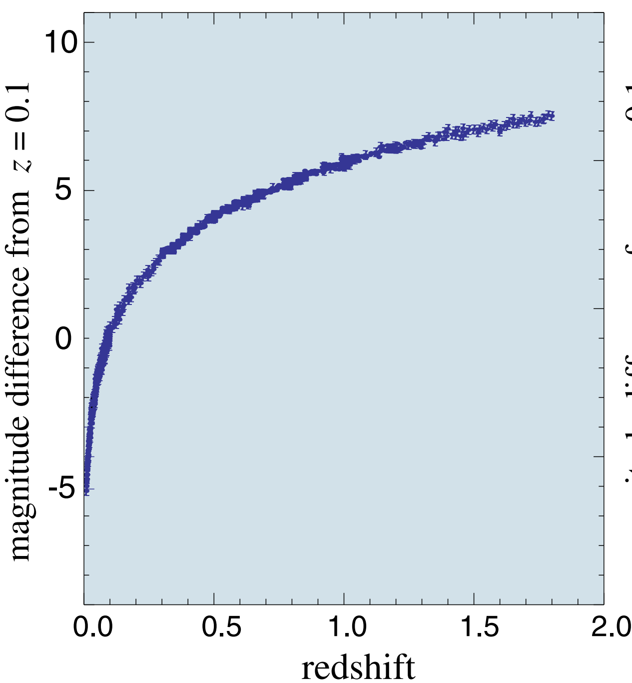
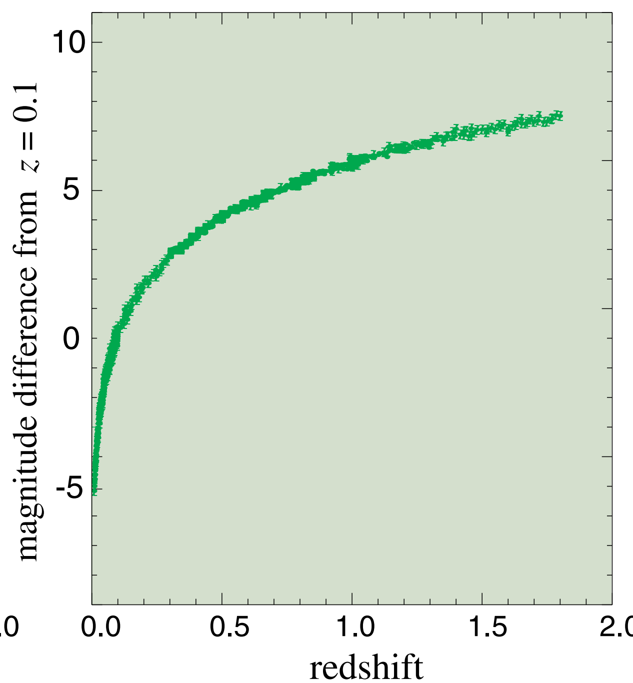


Group B:
* Si II in spectrum: type Ia
* in core of late-type spiral host
* faint UV: high metallicity
* fast rise time: low Ni56 mass
* spectral feature velocities 9000 < v < 10000 km/s

•
•
•



Group C:
* Si II in spectrum: type Ia
* in outskirts of late-type spiral host
* bright UV: low metallicity
* long rise time: high Ni56 mass
* spectral feature velocities 8000 < v < 9500 km/s

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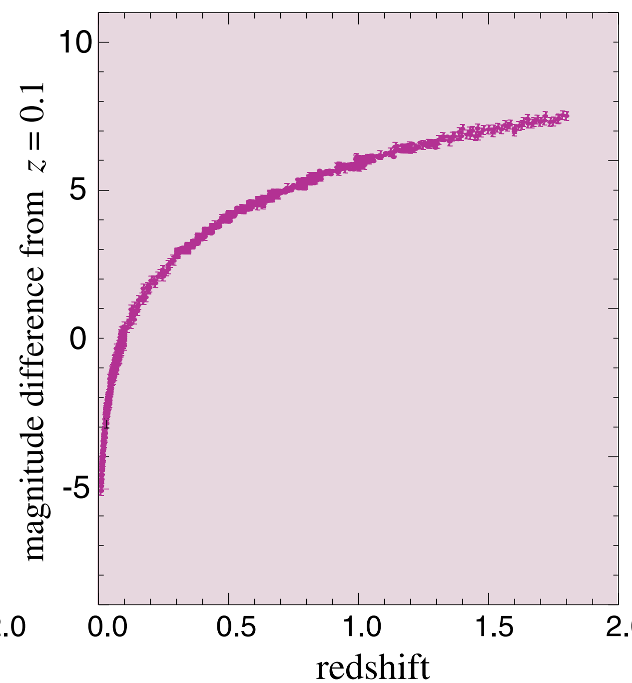
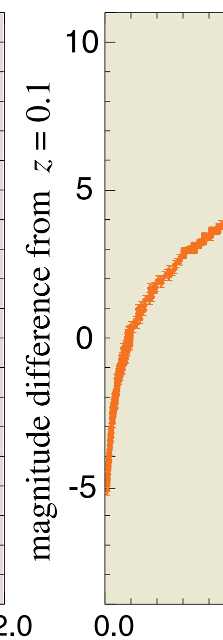
•

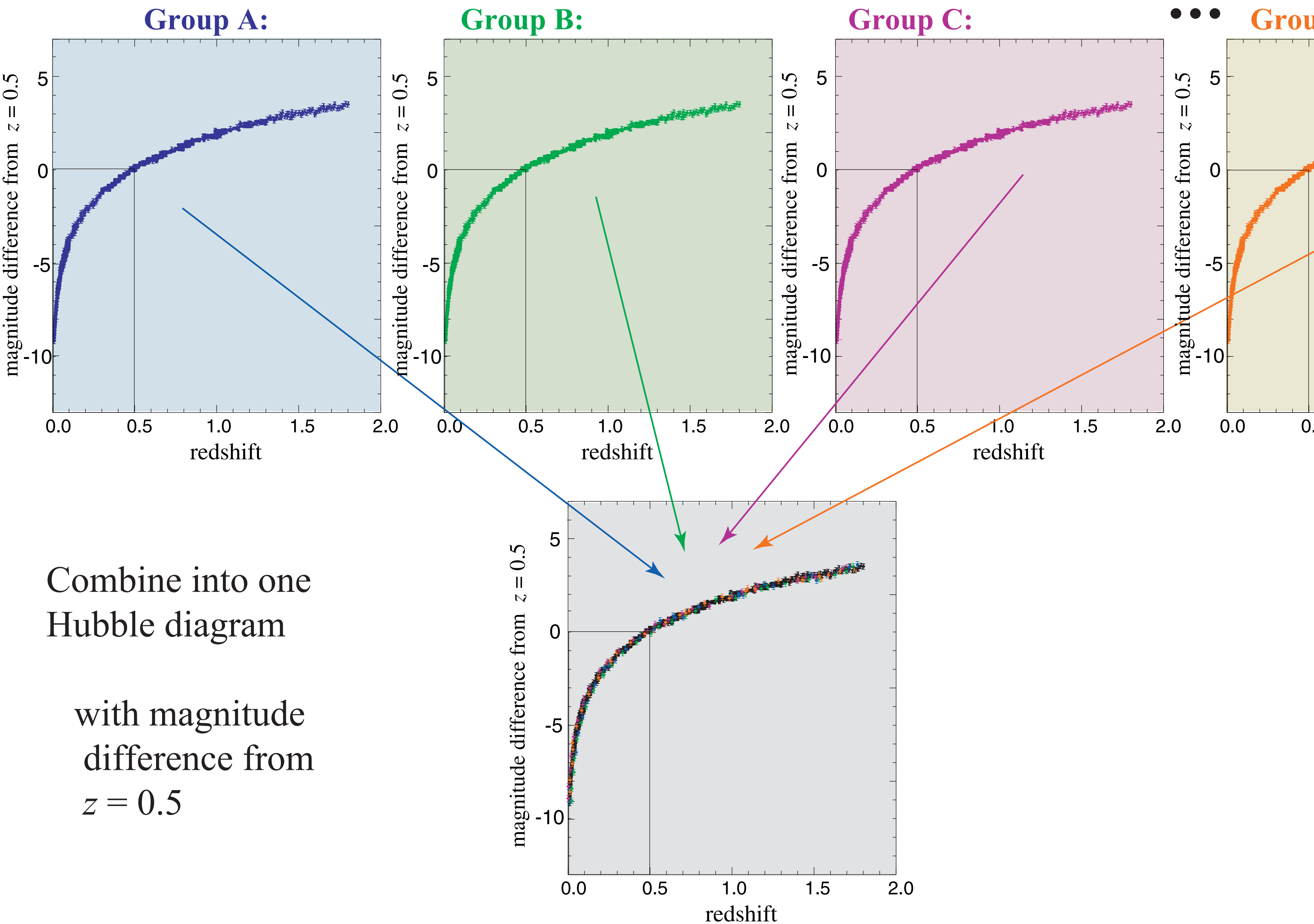
• • •

Gro
* Si II i
* in core
* brigh
* short
* spect 8000





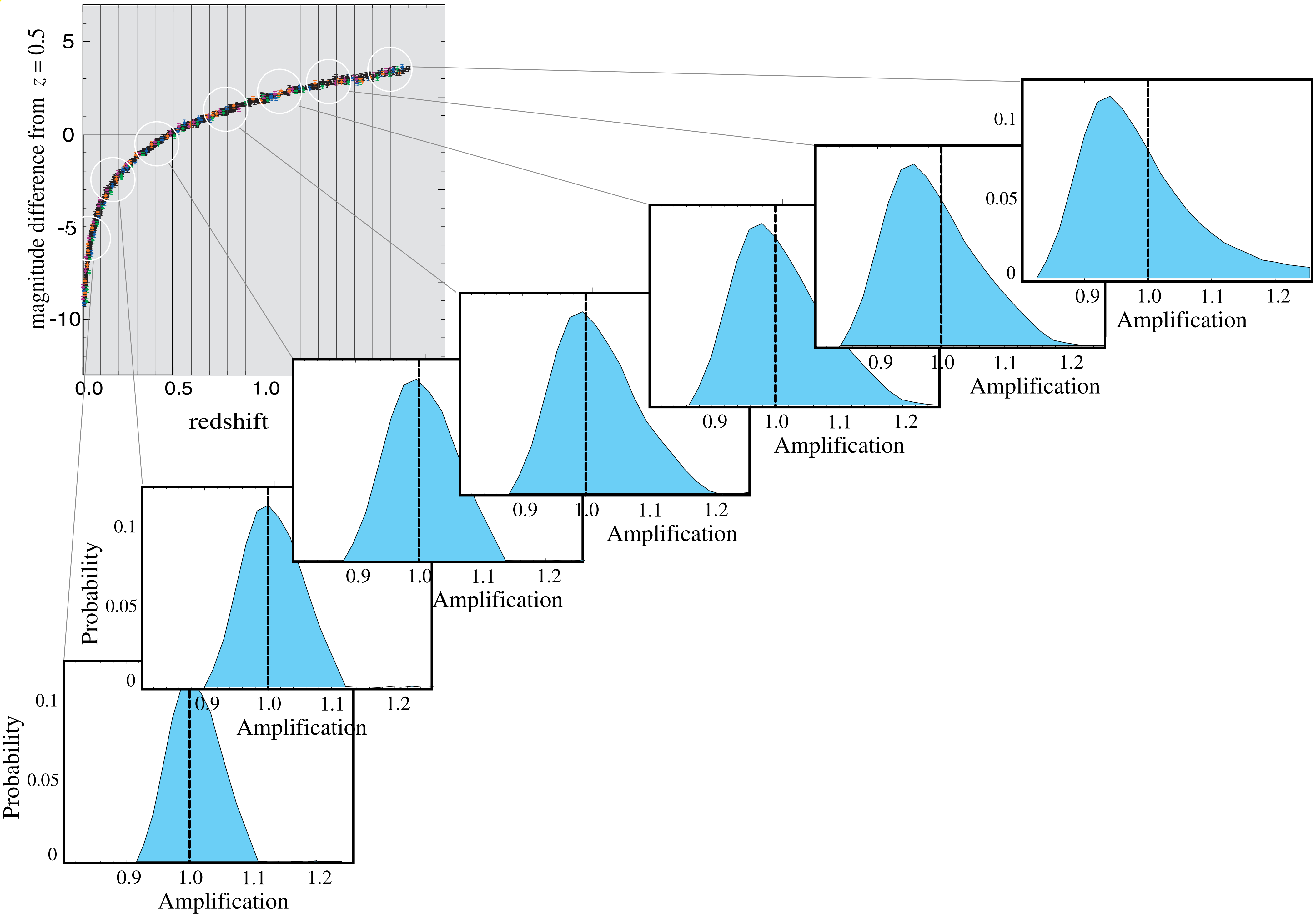
2 Each subset gets its own extinction-corrected Hubble diagram:



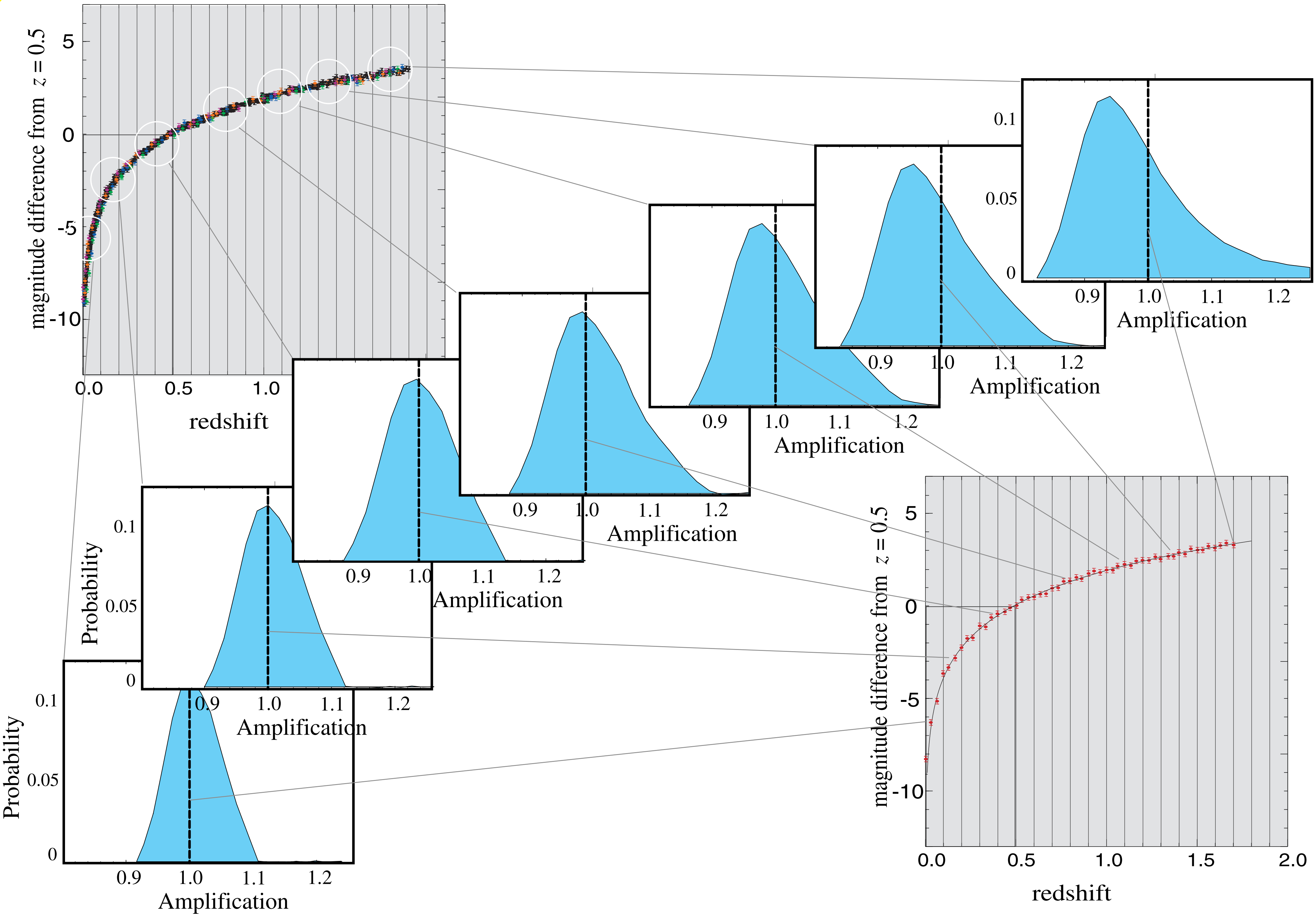
Combine into one Hubble diagram

with magnitude difference from $z = 0.5$

3 Break Hubble diagram into z slices to study lensing (de)amplification distribution:

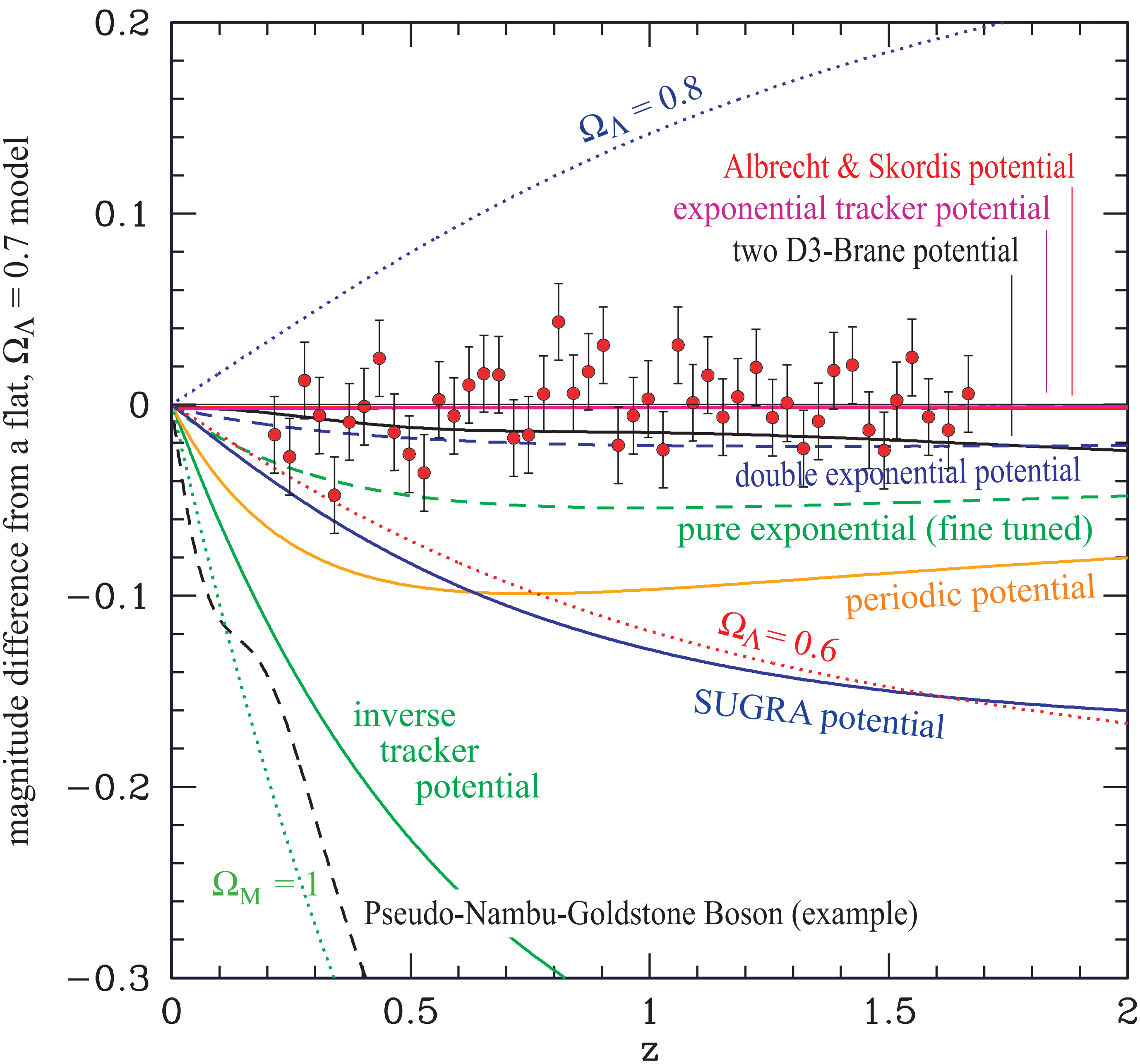


3 Fit/average lensing distributions to construct redshift-binned Hubble diagram:



SNAP SuperNova Acceleration Probe

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



based on

Weller & Albrecht (2001)

Example Measurement Requirements for Each Step

Sort into Like Subsets

1

Spectrum:

Si II feature 15σ per bin with 30A restframe resolution

UV features 5σ per bin

Lightcurve:

Rise time 3σ measurement 3.8 mag before max

Peak fit 15σ measurement 2 mag after max

Image:

Host galaxy morphology <0.1" dithered resolution

Extinction-corrected Hubble diagram

2

Spectrum & Lightcurve:

Cross-wavelength calibrated colors for photometry and spectroscopy from near-UV to near-IR (0.4 -- 1.7 μm)

Correct for lensing distributions

3

Image quality:

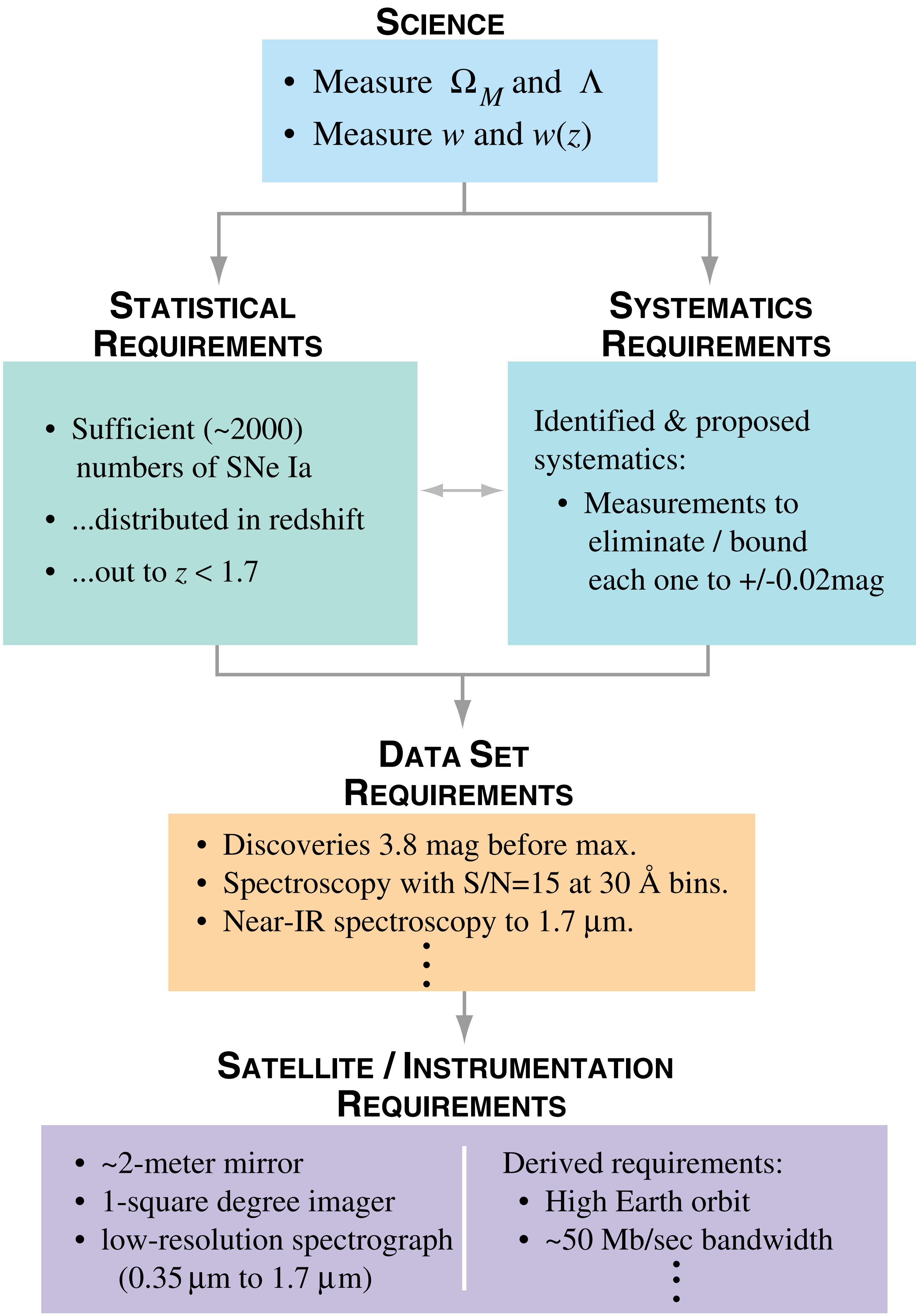
<0.1" dithered resolution for neigboring galaxy gravitational lensing map

Redshift range & statistics:

>~50 SNe per bin to obtain lensing distribution

SNAP SuperNova Acceleration Probe

3. Current Technical Status


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=15 at 30 Å bins.
• Near-IR spectroscopy to 1.7 µm.
SATELLITE / INSTRUMENTATION REQUIREMENTS
• ~2-meter mirror
• 1-square degree imager
• low-resolution spectrograph (0.35 µm to 1.7 µm)
Derived requirements:
• High Earth orbit
• ~50 Mb/sec bandwidth

SNAP SuperNova Acceleration Probe

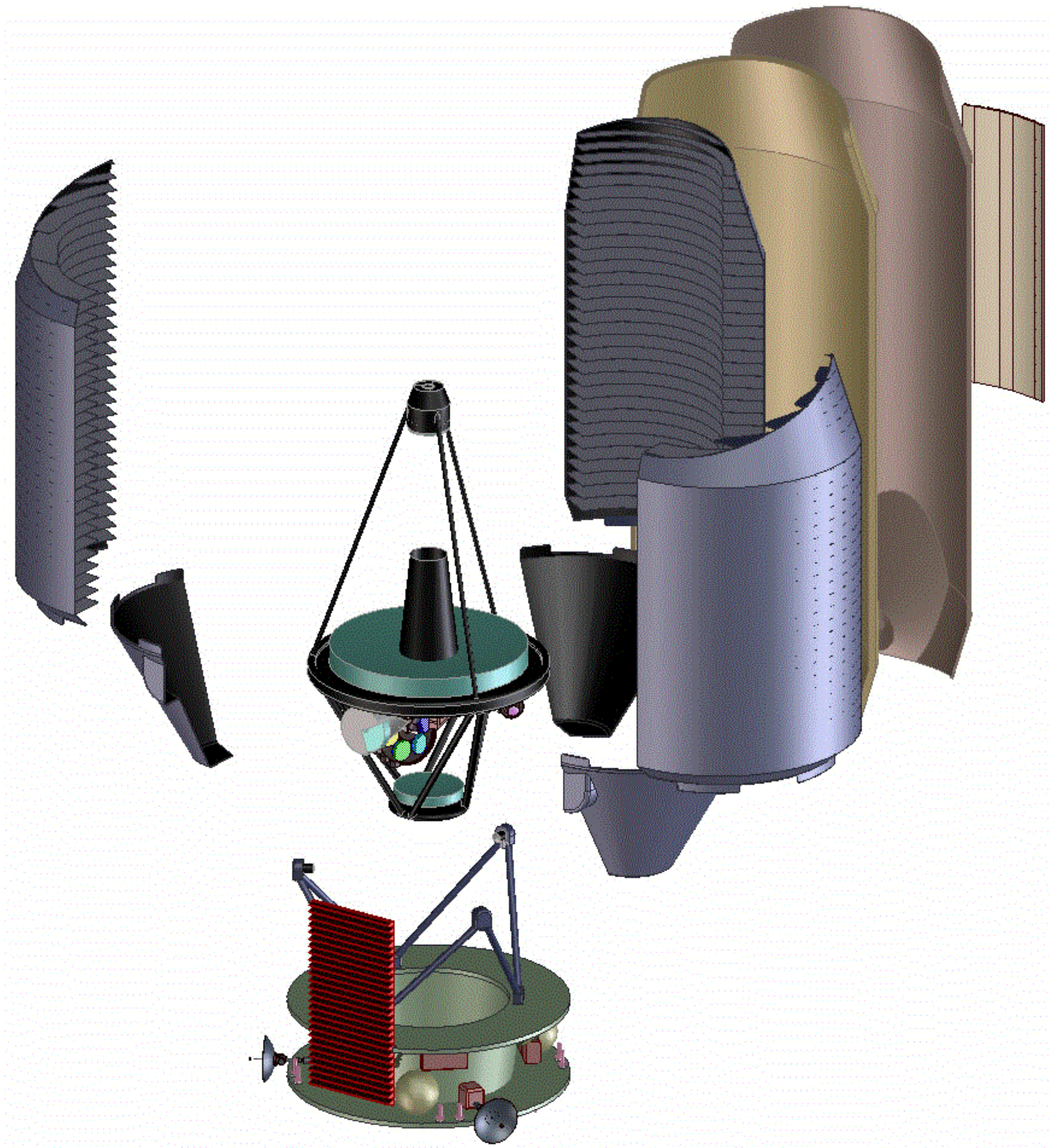
Simple Observatory consists of :

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*

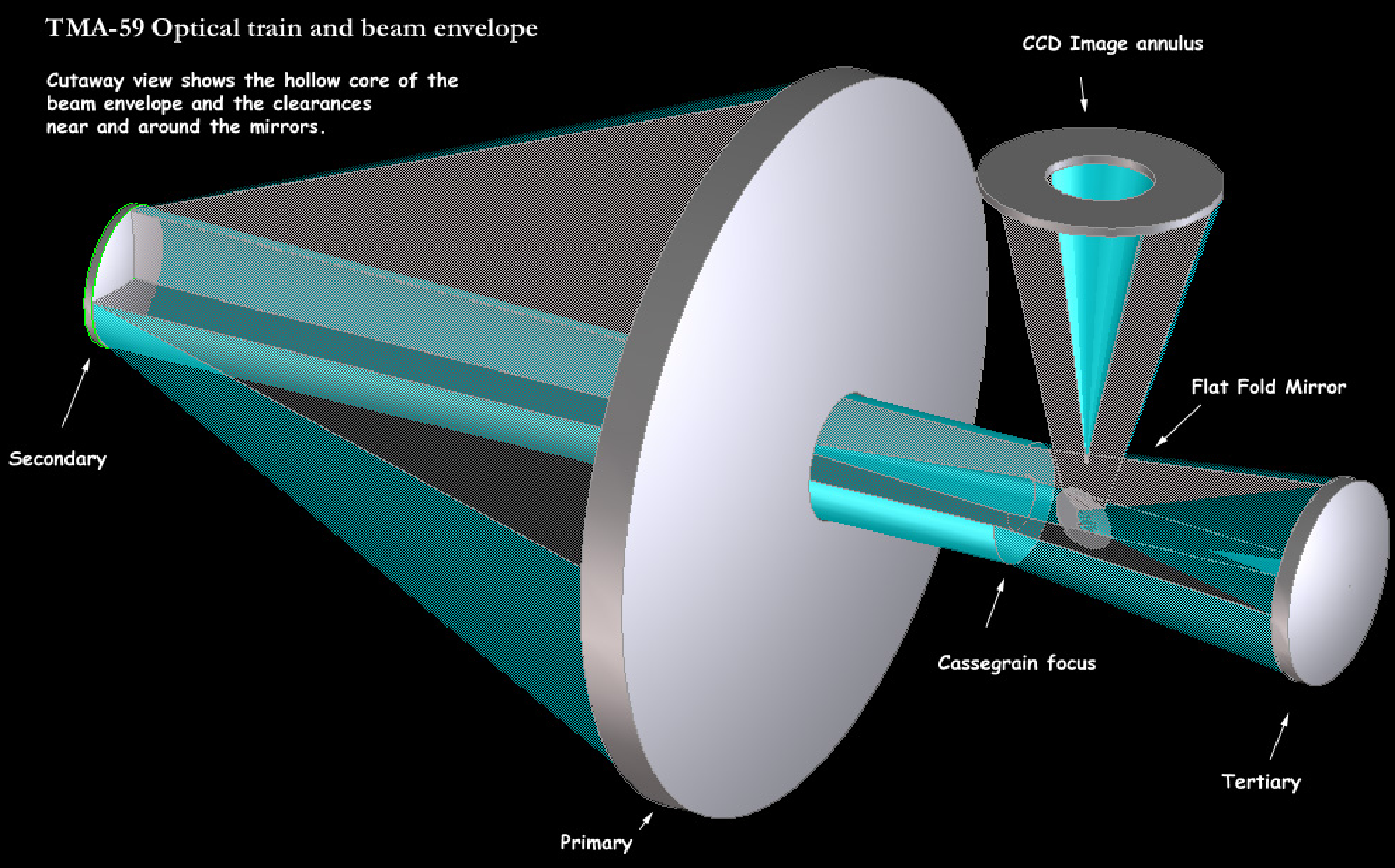


No moving parts (ex. shutter),
- **rigid simple structure.**

High-earth orbit:
- **excellent telemetry to ground station,**
- **no daily eclipses,**
- **passive cooling**

SNAP SuperNova Acceleration Probe

Optical Train



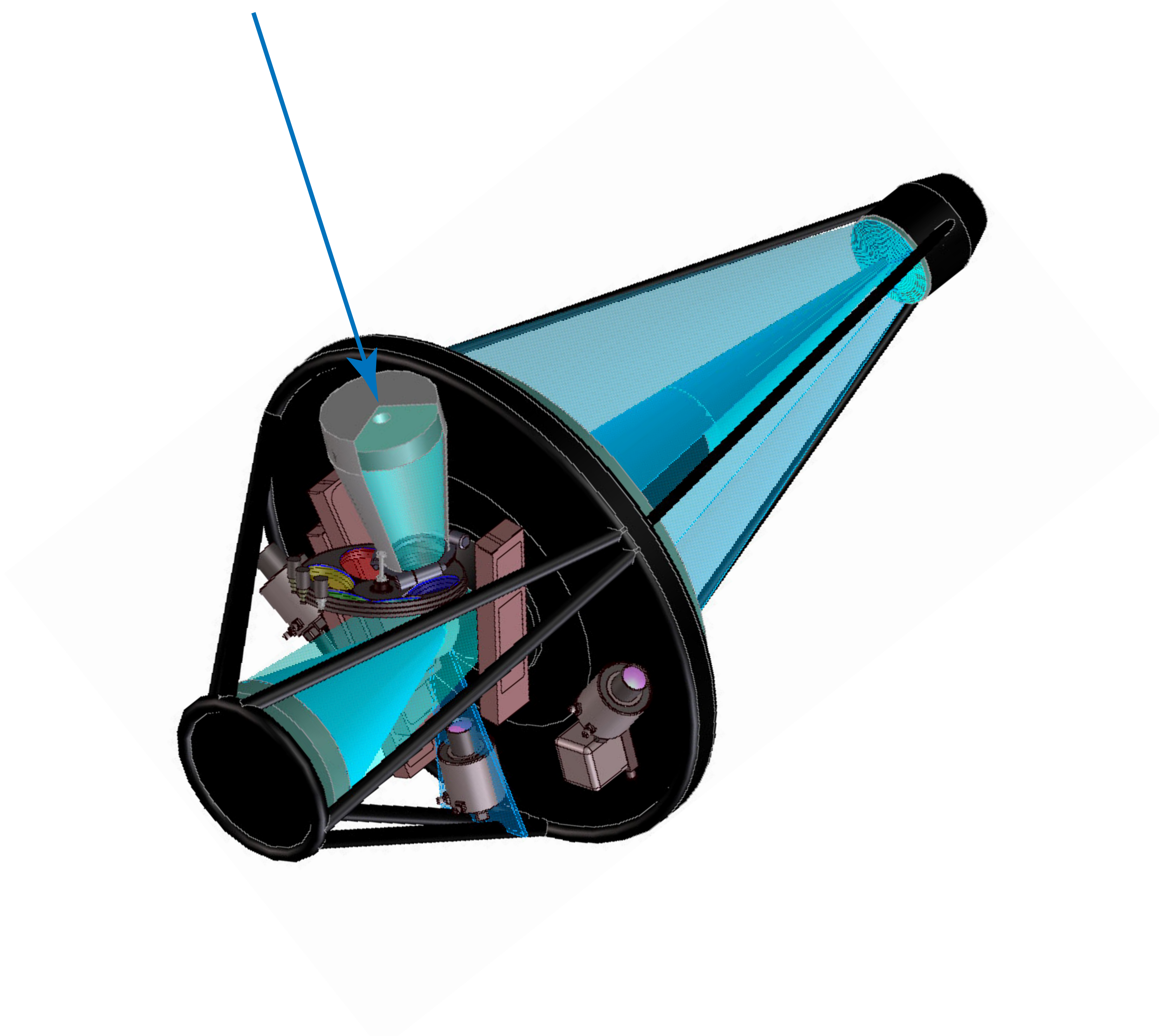
SNAP SuperNova Acceleration Probe

instrumentation

GigaCam Imager & **Spectrograph**

1 square degree field of view
144 CCD's
+ 36 HgCdTe

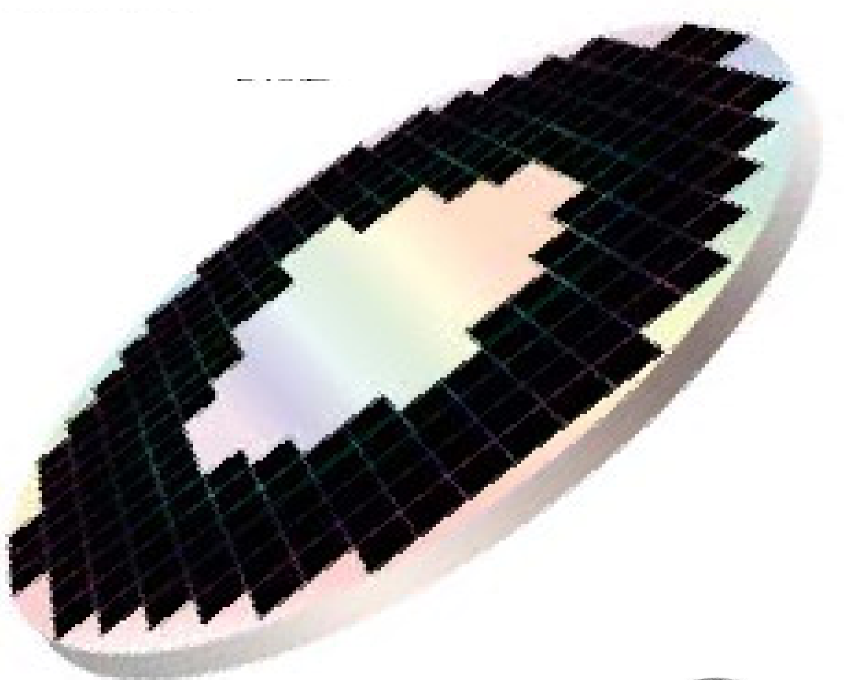
low resolution
high throughput
350 nm -- 1700 nm

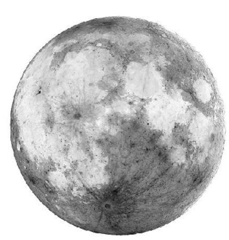


SNAP SuperNova Acceleration Probe

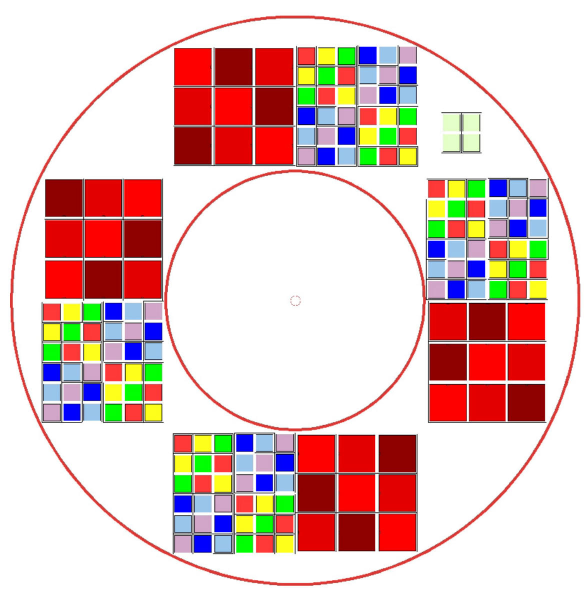
GigaCAM, a one billion pixel array

- Depending on pixel scale, approximately 1 billion pixels.
- 144 CCD detectors and 36 HgCdTe devices.
- Larger than SDSS camera, smaller than BaBar Vertex Detector (1 m^2).
- 50–100x multiplex advantage makes this experiment work.



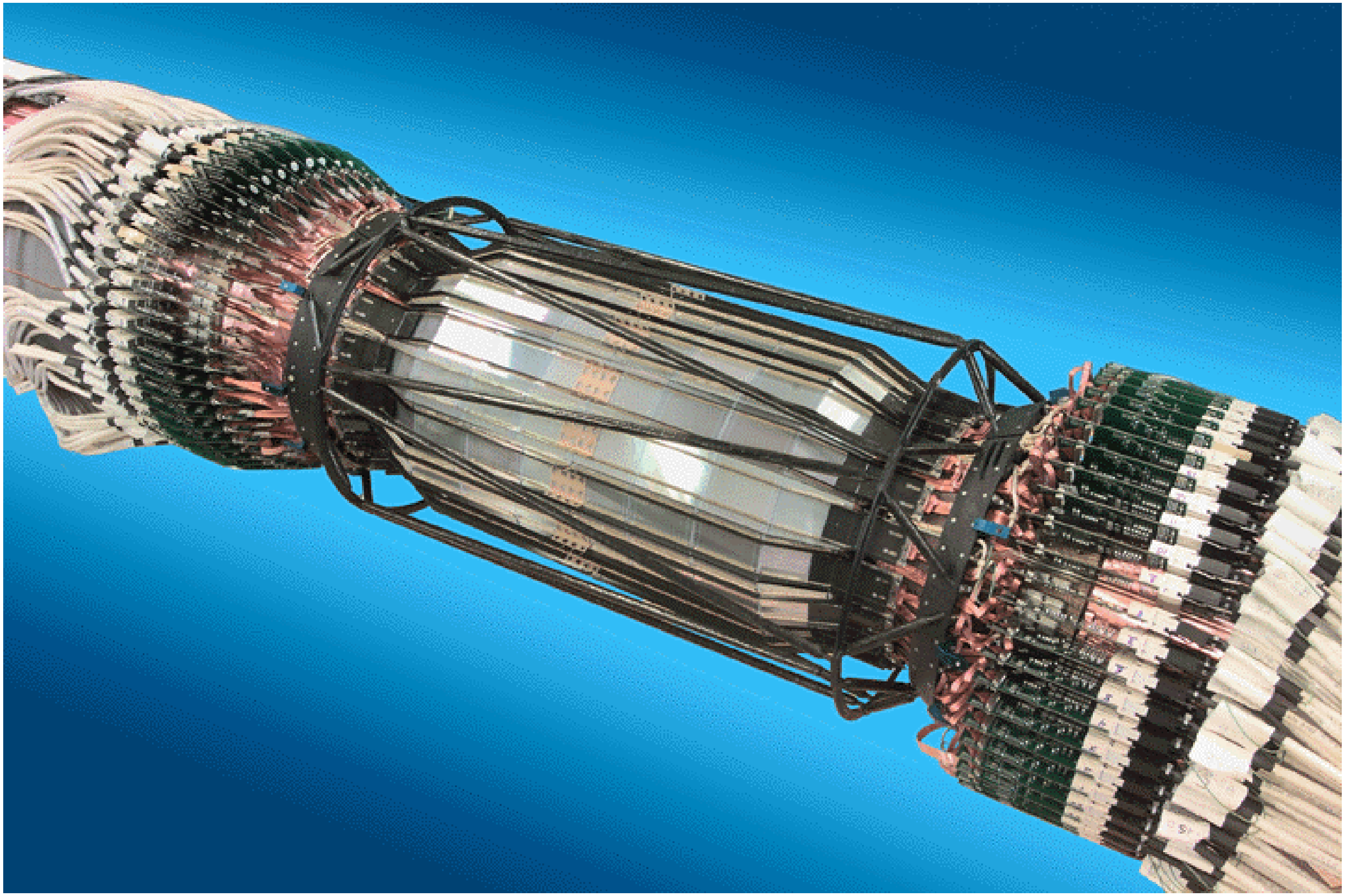


The Moon
(for scale)



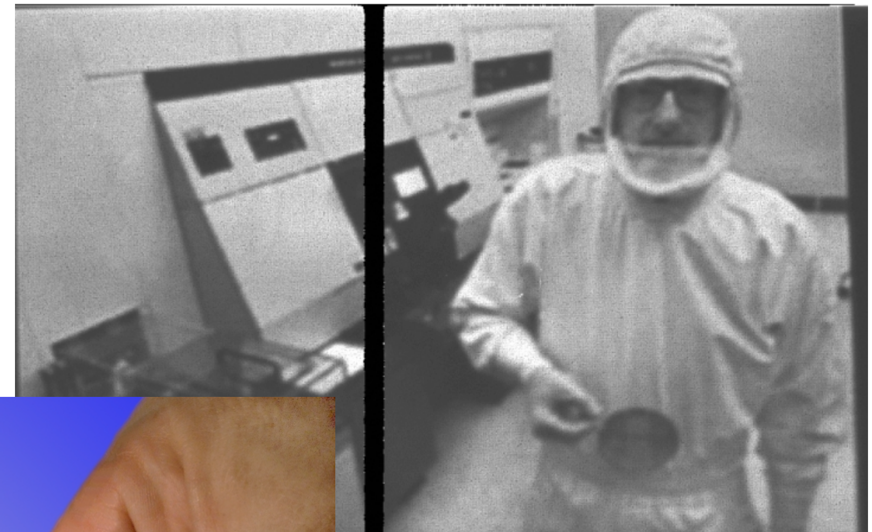
3 IR filters on HgCdTe
6 visible filters on CCD

BaBAR Silicon Vertex Detector (~1m^2 Si)

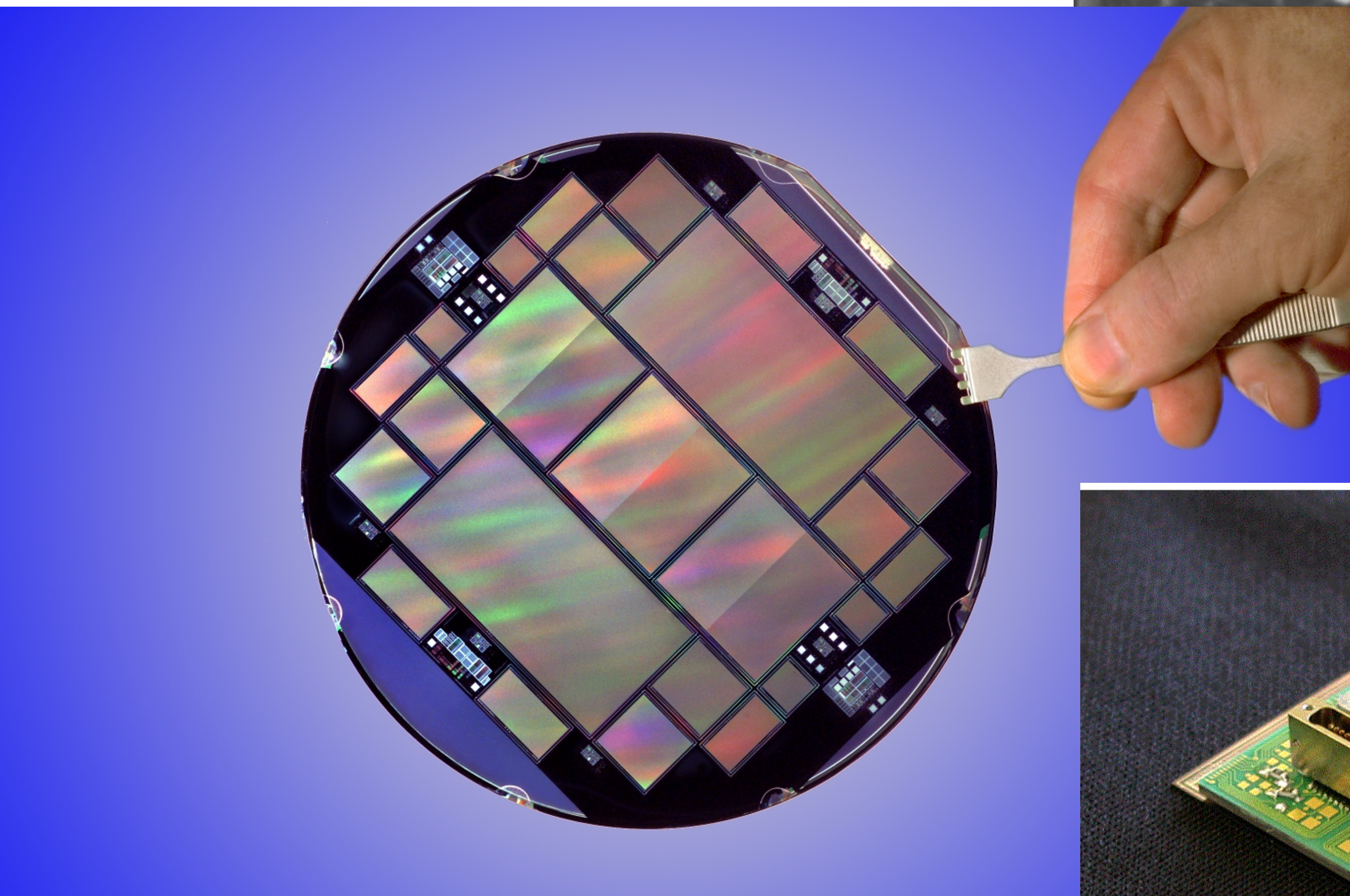


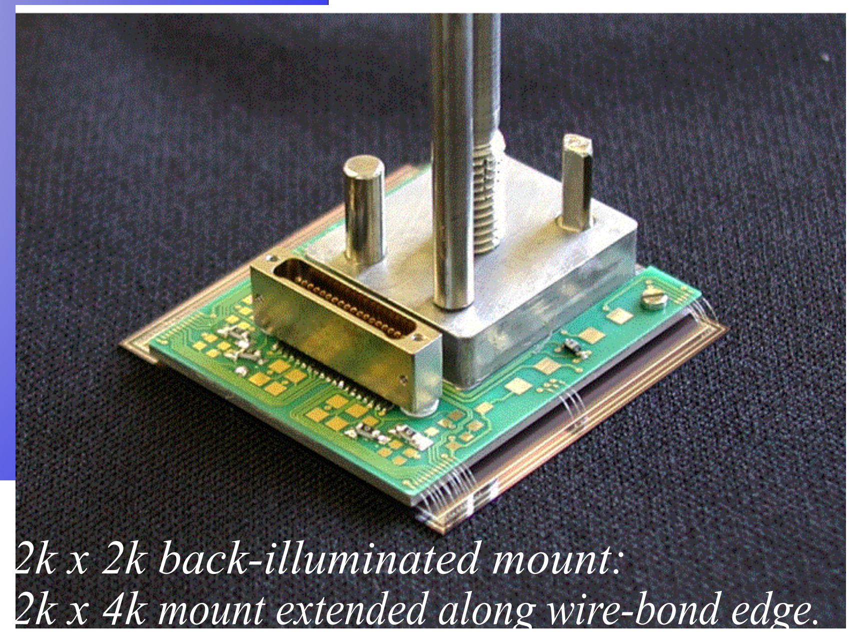
SNAP SuperNova Acceleration Probe

CCD fabrication and mount assembly



First back-illuminated image with new mount. CCD is engineering grade used for assembly practice.



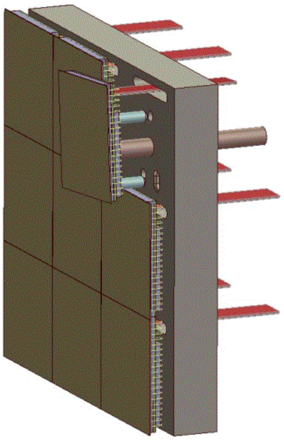


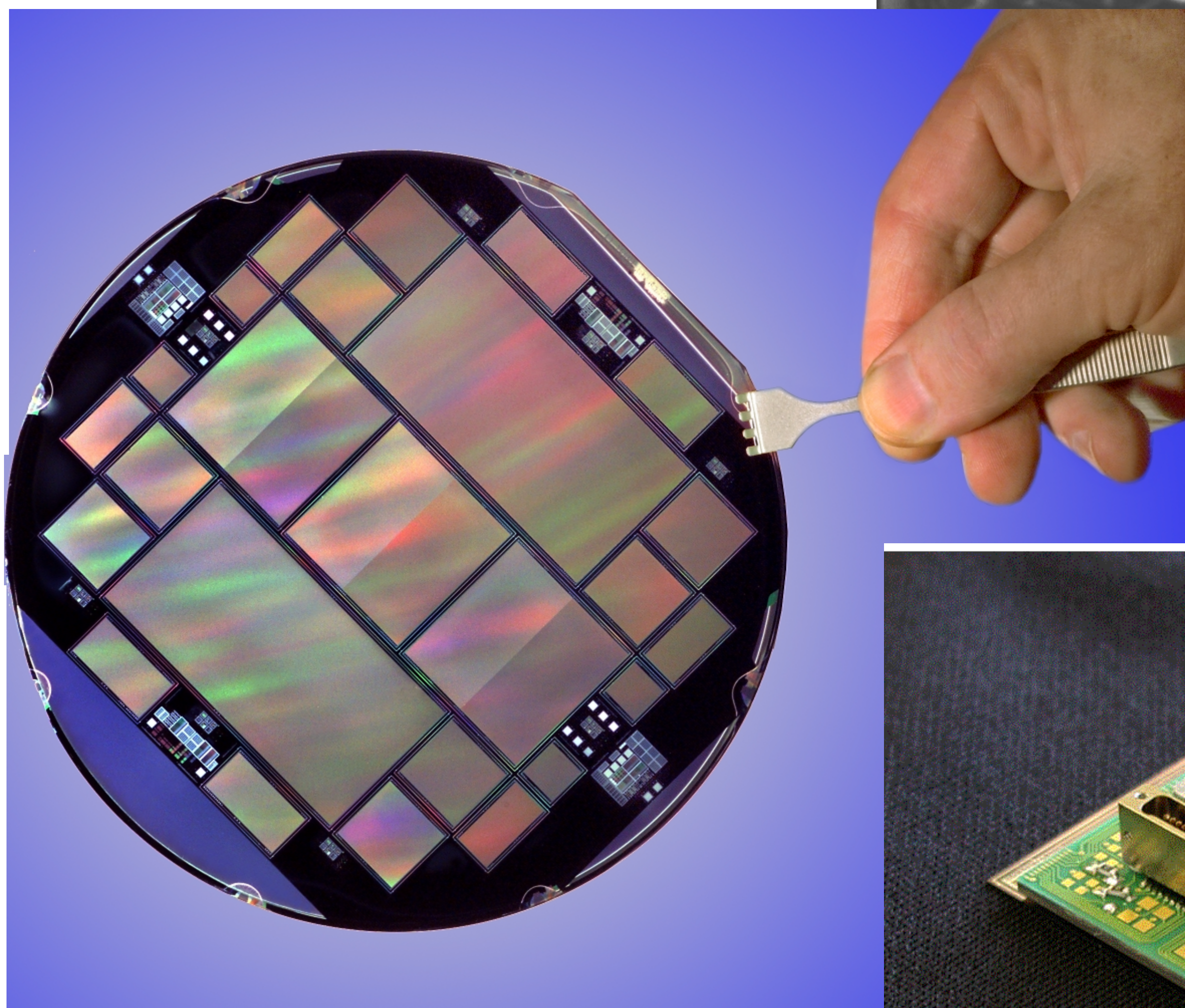
2k x 2k back-illuminated mount:
2k x 4k mount extended along wire-bond edge.

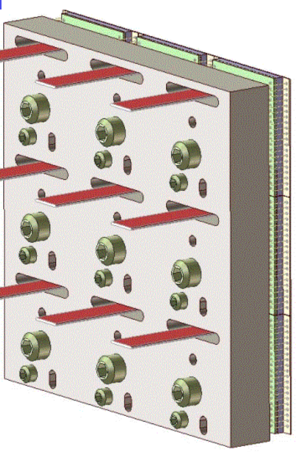
SNAP SuperNova Acceleration Probe

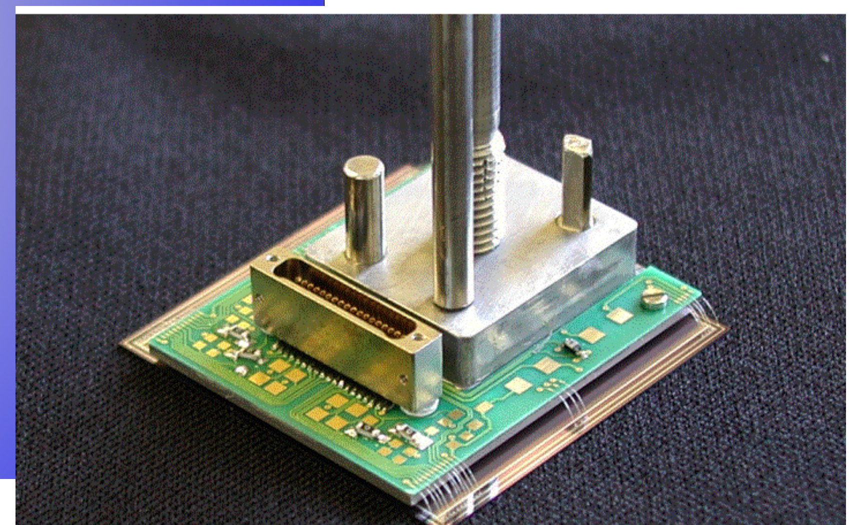
CCD fabrication and mount assembly

First back-illuminated image with new mount. CCD is engineering grade used for assembly practice.





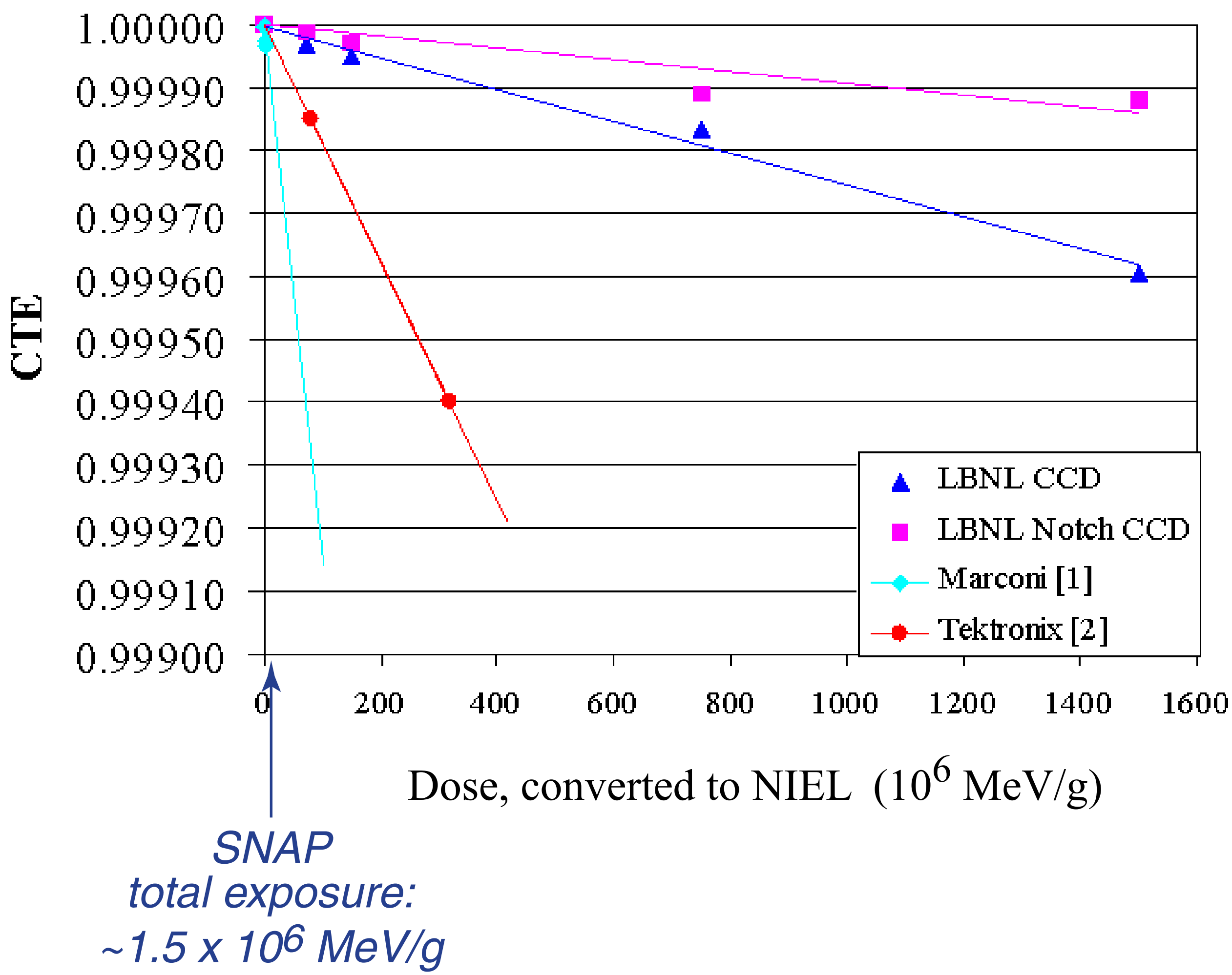




2k x 2k back-illuminated mount:
2k x 4k mount extended along wire-bond edge.

SNAP SuperNova Acceleration Probe

Charge Transfer Efficiency vs Radiation Dosage
Comparison of LBNL CCDs to conventional CCDs



[1]L.Cawley, C.Hanley, "WFC3 Detector Characterization Report #1: CCD44 Radiation Test Results," Space Telescope Science Institute Instrument Science Report WFC3 2000-05, Oct.2000

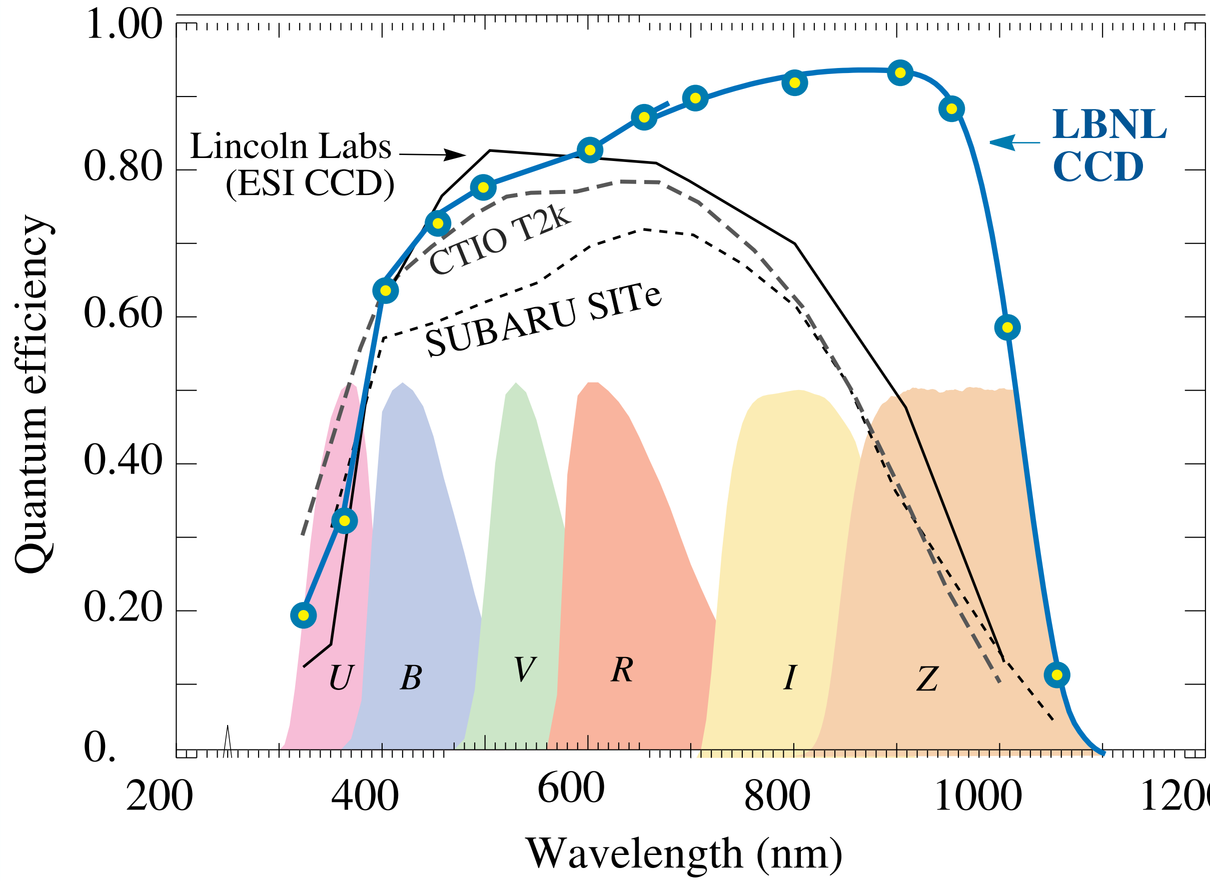
[2] T. Hardy, R. Murowinski, M.J. Deen, "Charge transfer efficiency in proton damaged CCDs," IEEE Trans. Nucl. Sci., 45(2), pp. 154-163, April 1998

LBNL CCDs at NOAO

See September 2001 newsletter at http://www.noao.edu

Cover picture taken at WIYN 3.5m with LBNL 2048 x 2048 CCD (Dumbbell Nebula, NGC 6853)

High quantum efficiency from near UV to near IR
No thinning: no fringing, high yield..

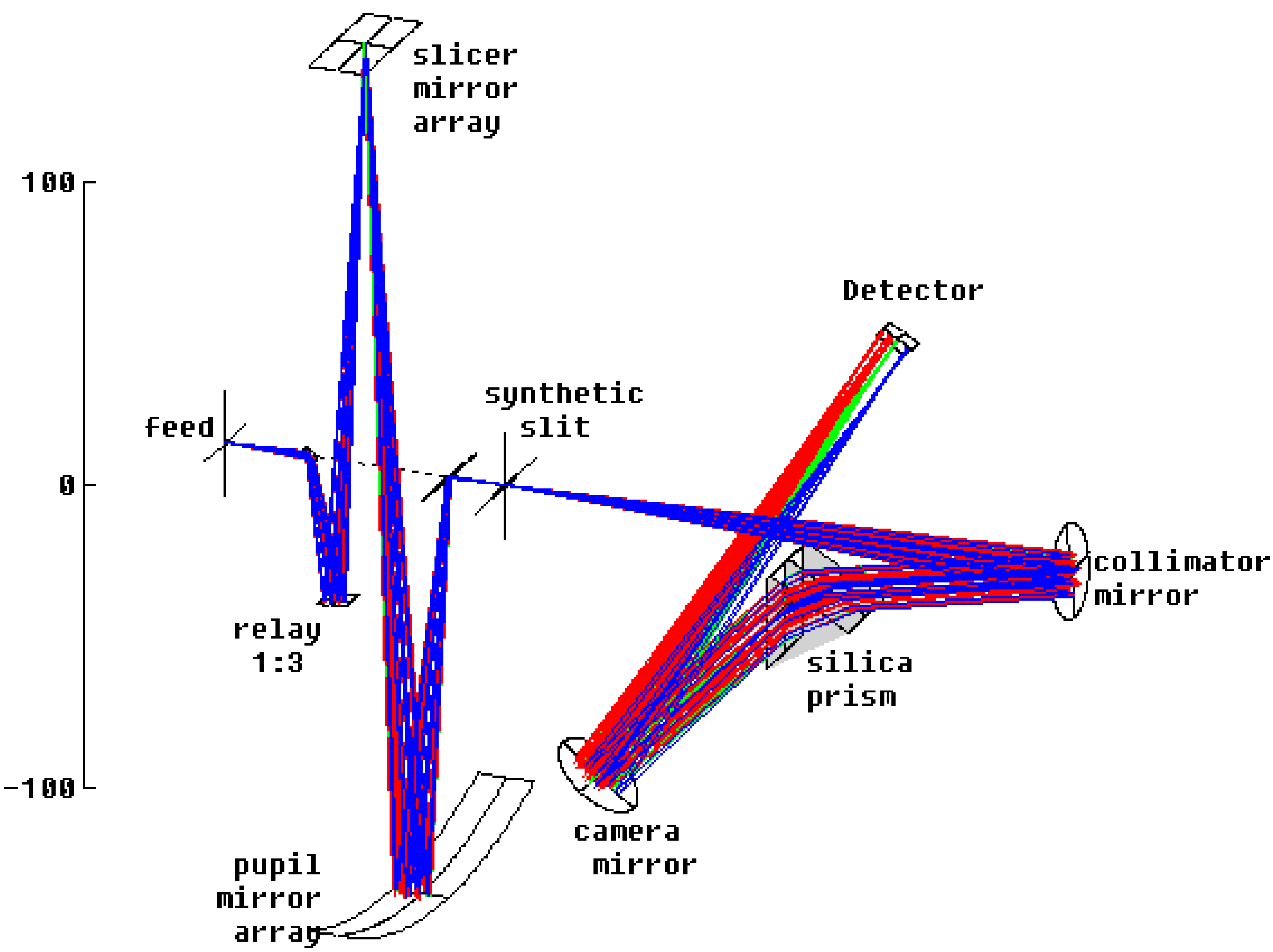


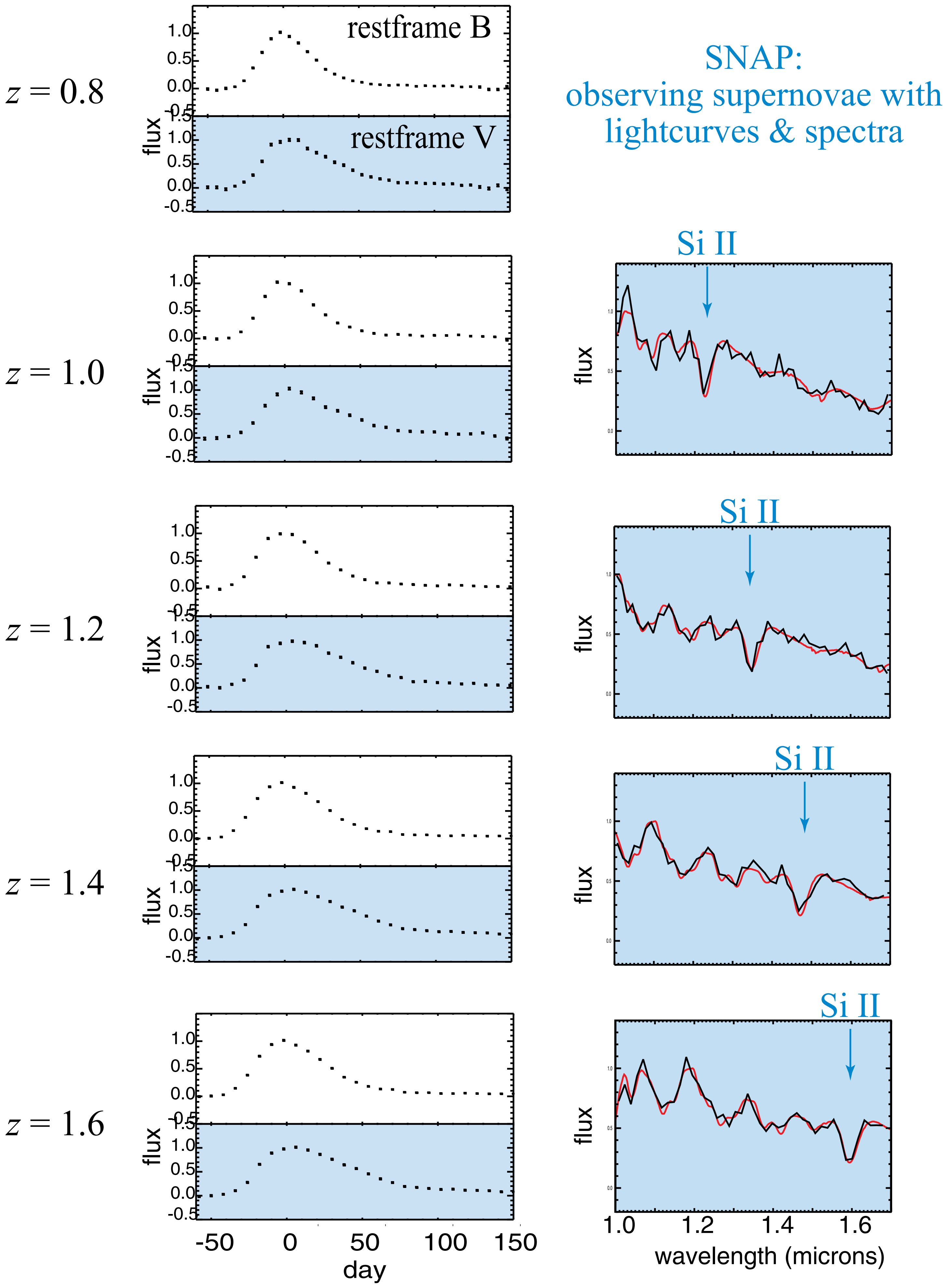
Science studies to date at NOAO using LBNL CCD's:

1. Near-earth asteroids
2. Seyfert galaxy black holes
3. LNBL Supernova cosmology

SNAP SuperNova Acceleration Probe

IFU Spectrometer Concept

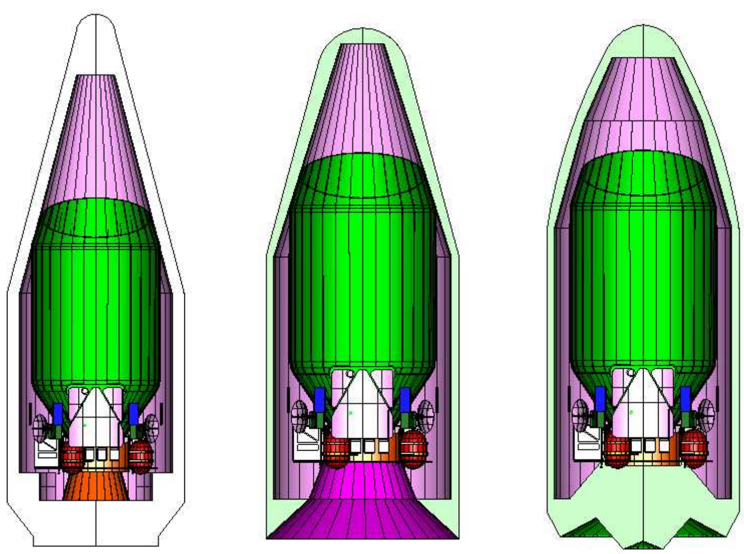



SNAP:
observing supernovae with
lightcurves & spectra
z = 0.8
z = 1.0
z = 1.2
z = 1.4
z = 1.6
restframe B
restframe V
flux
Si II
day
wavelength (microns)
-50
0
50
100
150
1.0
1.2
1.4
1.6

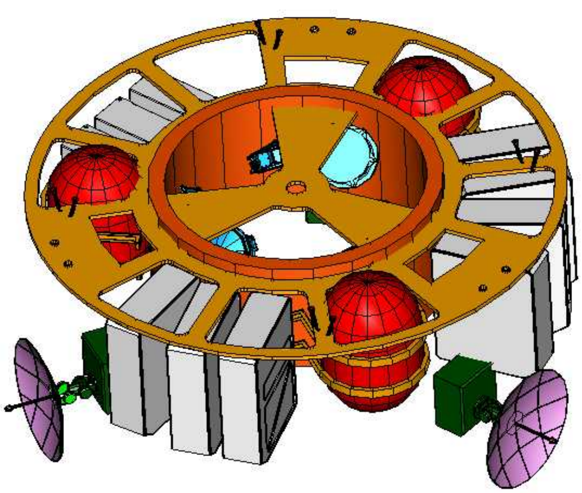
SNAP SuperNova Acceleration Probe

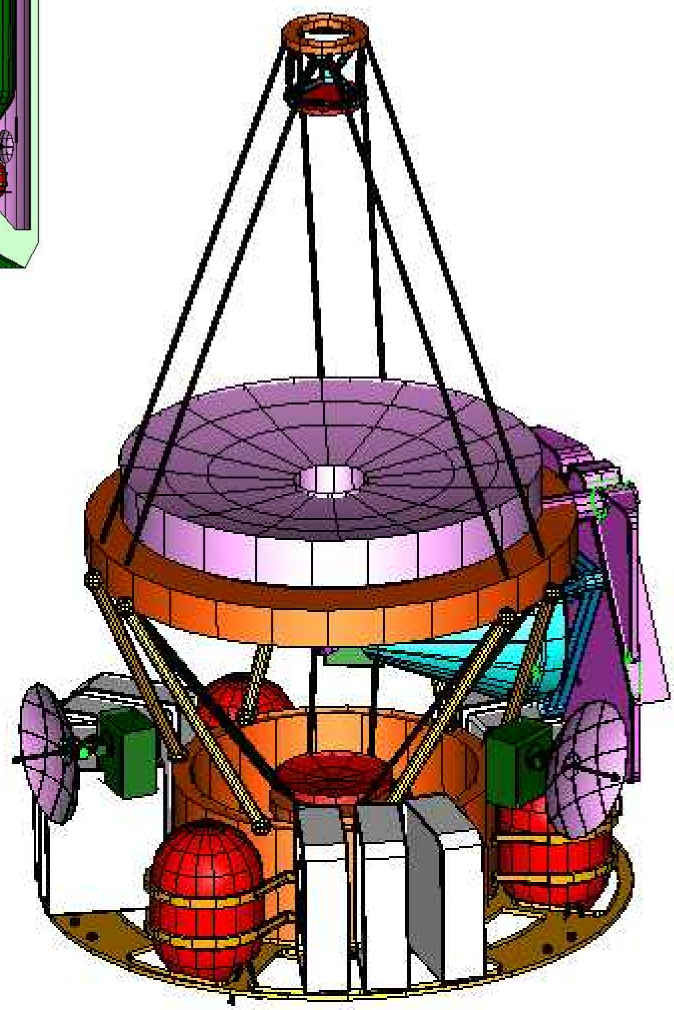
Two NASA Goddard multi-day intensive design studies:

- Goddard / Integrated Mission Design Center (IMDC) study in June 2001: no mission tallpoles.
- Goddard / Instrument Synthesis and Analysis Lab (ISAL) study in Nov. 2001: no technology tallpoles.
-



Atlas-EPF Delta-III Sea Launch





4. Project status & How SNAP fits in the science scene.

SNAP Collaboration

G. Aldering, C. Bebek, S. Deustua, W. Edwards, B. Frye, D. Groom, S. Holland, D. Kasen, R. Knop, R. Lafever, M. Levi, S. Loken, P. Nugent, S. Perlmutter, K. Robinson (*Lawrence Berkeley National Laboratory*)

E. Commins, D. Curtis, G. Goldhaber, J. R. Graham, S. Harris, P. Harvey, H. Heetderks, A. Kim, M. Lampton, R. Lin, D. Pankow, C. Pennypacker, A. Spadafora, G. F. Smoot (*UC Berkeley*)

C. Akerlof, D. Amidei, G. Bernstein, M. Campbell, D. Levin, S. McKee, M. Schubnell, G. Tarle , A. Tomasch (*U. Michigan*)

P. Astier, J.F. Genat, D. Hardin, J.- M. Levy, R. Pain, K. Schamahneche (*IN2P3*)

A. Baden, J. Goodman, G. Sullivan (*U. Maryland*)

R. Ellis, M. Metzger (*CalTech*)

A. Fruchter (*STScI*)

L. Bergstrom, A. Goobar (*U. Stockholm*)

C. Lidman (*ESO*)

J. Rich (*CEA/DAPNIA*)

A. Mourao (*Inst. Superior Tecnico,Lisbon*)

International collaboration is growing -- currently 15 institutions.

SNAP SuperNova Acceleration Probe

Project History and Status

* SNAP project still in study phase, conceived in March 1999

* Project is being developed as a multi-agency partnership:
Team that produced current results was supported by
DOE, NASA, and IN2P3.

Peer review of science (260 page proposal) by
DOE & NSF's SAGENAP panel, March 2000:
Strong endorsement of science,
and recommendation for study funding.
(Reports to HEPAP to establish High Energy Physics' priorities)

* Recent DOE/Science & R&D Review (Jan 2001):
"SNAP is a science-driven project with compelling scientific goals."
"SNAP will have a unique ability to measure the variation in the equation of state of the universe."
"Implications for particle physics: We believe that it is not an overstatement to say that the Type Ia supernova measurements will uniquely address issues at the very heart of the field…"

* Study phase proposal for French Space Agency submitted (Nov 2001), will be reviewed in March 2002.

NAS Physics Survey Overview

"Cosmology touches fundamental physics in many different ways. The value of the cosmological constant is one of the major unsolved problems in the theory of the basic interactions. A definitive measurement of this central parameter from cosmology is critically important for the future development of particle physics."

"Exciting questions are being addresssed: Is the expansion of the universe today accelerating as a result of some mysterious form of energy?"

"Because of the profound relationship between physics at the smallest distance scales and the details of the early universe and dark mass-energy, [precison cosmology] will open a new window for physics."

NAS Committee on Gravitational Physics

"Current observations of [supernovae] suggest that the expansion rate of the unvierse is accelerating. This surprising result suggests the existence of a cosmological constant whose value is of fundamental importance for physics. Future observations can help reduce both statistical and systematic errors in these results."

"Key questions for gravitational physics: ...What is the value of the cosmological constant?"

"The value of the cosmological constant is important not only for classical gravity and cosmology, but also for quantum gravity."

SNAP SuperNova Acceleration Probe

Three National Prioritization Panels' Recommendations

Astronomy & Astrophysics

NRC Decadal Survey:

"One of the most exciting developments of the past decade has been the discovery that the cosmological constant may not be zero — our universe appears to be filled with dark energy."

"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."

SNAP was formulated after the Decadal Survey's data collection phase.

Physics

HEPAP 20-Year Planning Report:

"Modern cosmology is closely connected with particle physics. For example, cosmological measurements of dark energy and particle dark matter have direct implications for particle physics."

"Dark energy can be probed by a number of techniques. Among the most powerful are measurements of the expansion rate of the universe from observations of Type Ia supernovae."

Report gives a strong endorsement for continued development of SNAP.

Intersection of Physics and Astronomy

NRC Committee on the Physics of the Universe:

"Deciphering the nature of dark matter and dark energy is one of the most important goals in the physics of the universe. Resolving both puzzles is key to advancing our understanding not only of cosmology but also fundamental physics."

"Observations of distant supernovae can probe the detailed expansion history directly back to redshifts of around 2.... Large-field-of-view telescopes are needed to find larger and more uniform samples of supernovae."

Committee reviewed SNAP in July 2001 as part of their Phase II study of specific projects (to be released next spring).

SNAP SuperNova Acceleration Probe

Science Goals for The First Wide-field Survey in Space

A Resource for the Science Community: The *only* wide-field deep survey in space -- with HST resolution.

- SNAP main survey will be 6300x larger (and somewhat deeper) than the biggest HST deep survey, the ACS survey
- Complementary to NGST: target selection for rare objects
- Can survey 3000 sq. deg in a year to I = 29 or J = 28 (AB mag) .

→ Archive data distributed

→ Guest Survey Program

Whole sky can be observed every few months

SNAP SuperNova Acceleration Probe

Grass-roots Support

January 2001 AAS meeting
1 dedicated session, 9 talks, 4 posters
January 2002 AAS meeting
2 dedicated sessions, 19 talks, 6 posters:

Oral Session 111. Science with Wide Field Imaging in Space:

The Astronomical Potential of Wide-field Imaging from Space	S. Beckwith (Space Telescope Science Institute)
Galaxy Evolution: HST ACS Surveys and Beyond to SNAP	G. Illingworth (UCO/Lick, U. of California)
Studying Active Galactic Nuclei with SNAP	P.S. Osmer (OSU), P.B. Hall (Princeton/Catolica)
Distant Galaxies with Wide-Field Imagers	K. M. Lanzetta (State U. of NY at Stony Brook)
Angular Clustering and the Role of Photometric Redshifts	A. Conti, A. Connolly (University of Pittsburgh)
SNAP and Galactic Structure	I. N. Reid (STScI)
Star Formation and Starburst Galaxies in the Infrared	D. Calzetti (STScI)
Wide Field Imagers in Space and the Cluster Forbidden Zone	M. E. Donahue (STScI)
An Outer Solar System Survey Using SNAP	H.F. Levison, J.W. Parker (SwRI), B.G. Marsden (CfA)

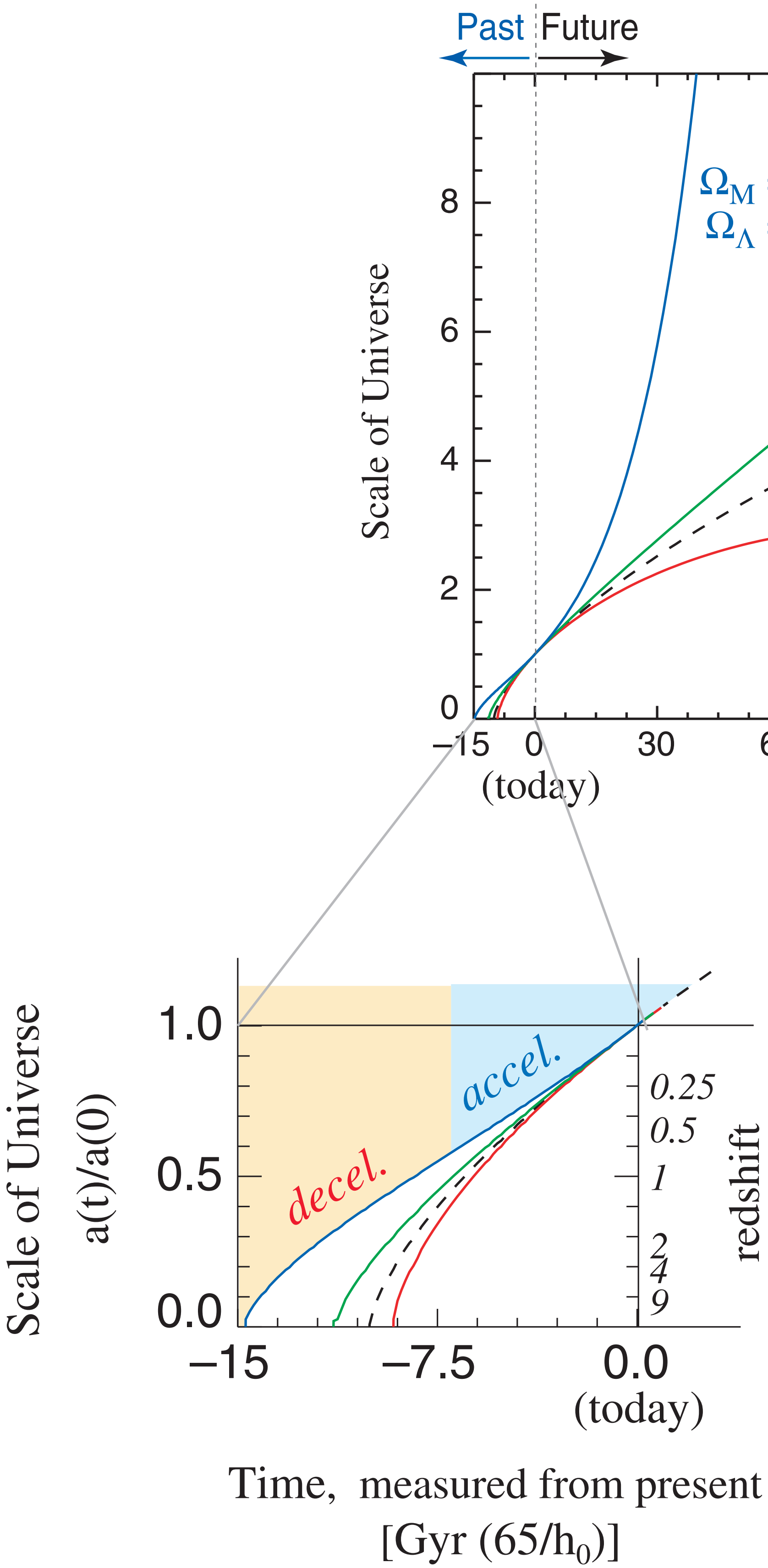
Oral Session 116. Cosmology with SNAP:

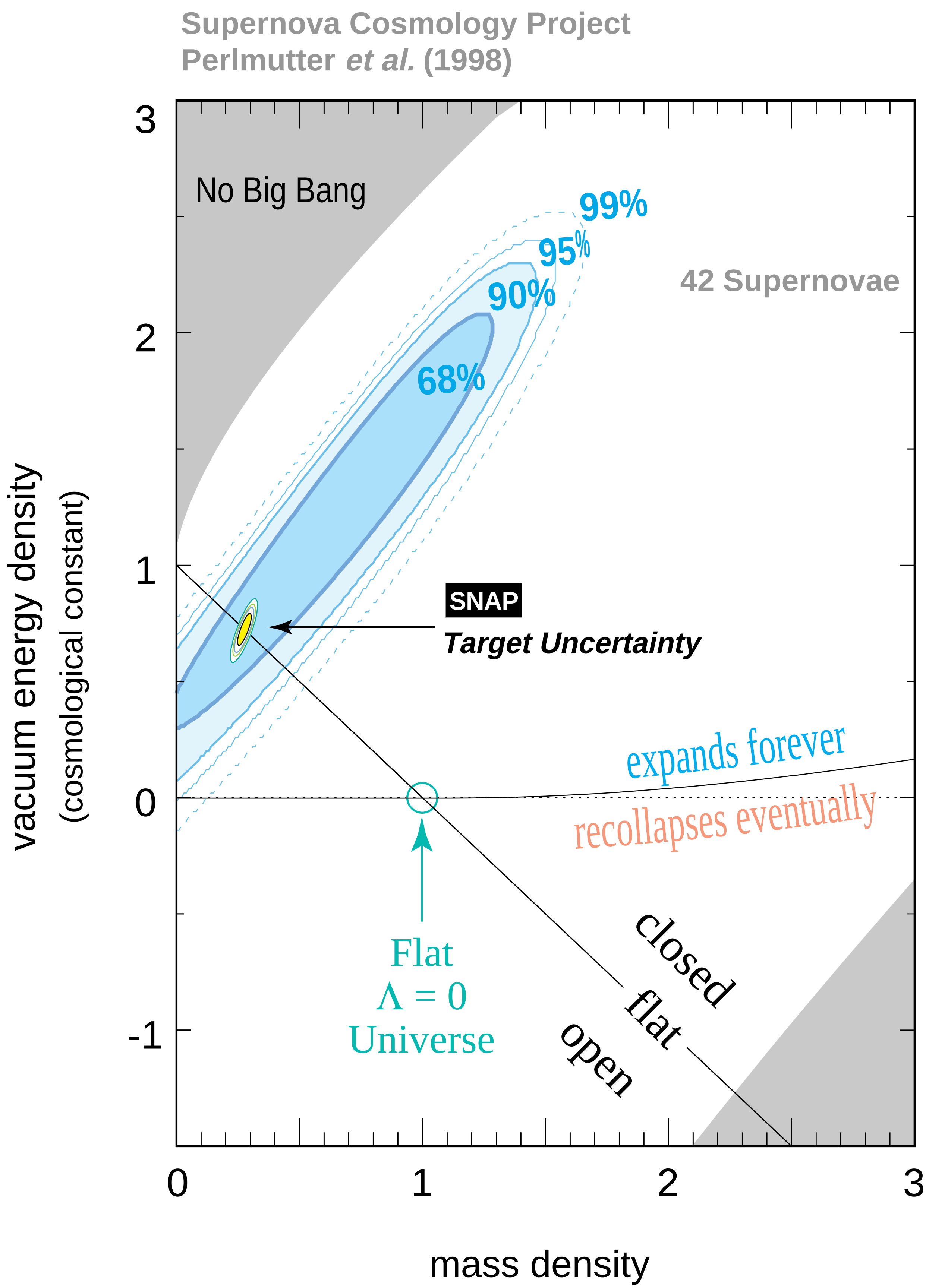
Dark Energy or Worse	S. Carroll (University of Chicago)
The Primary Science Mission of SNAP	S. Perlmutter (Lawrence Berkeley Laboratory),
The Supernova Acceleration Probe:mission design & core survey	T. A. McKay (University of Michigan)
Sensitivities for Future Space- and Ground-based Surveys	G. M. Bernstein (Univ. of Michigan)
Constraining the Properties of Dark Energy using SNAP	D. Huterer (Case Western Reserve University)
Type Ia Supernovae as Distance Indicators for Cosmology	D. Branch (U. of Oklahoma)
Weak Gravitational Lensing with SNAP	A. Refregier (Cambridge), Richard Ellis (Caltech)
Strong Gravitational Lensing with SNAP	R. D. Blandford, L. V. E. Koopmans, (Caltech)
Strong lensing of supernovae	D.E. Holz (ITP, UCSB)

Poster Session 64. Overview of The Supernova/Acceleration Probe:

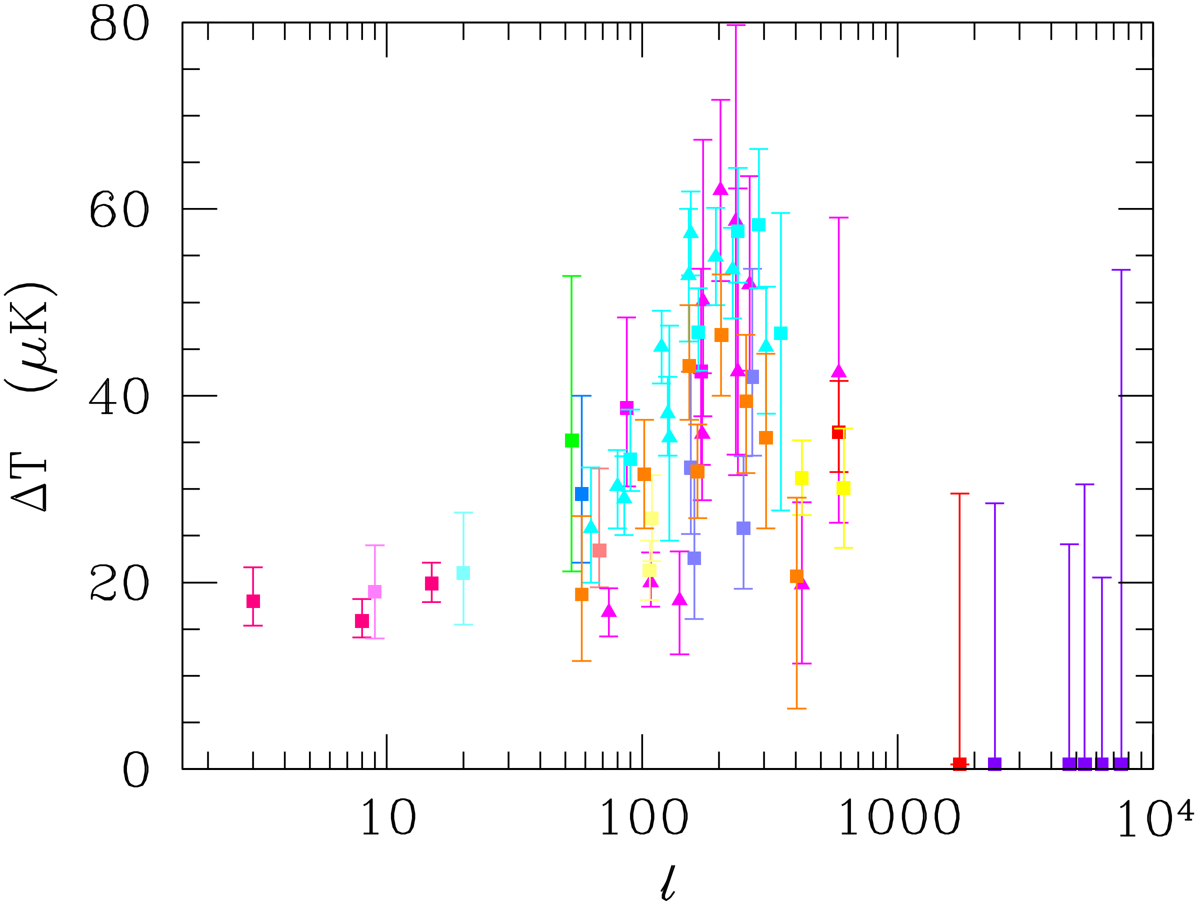
Supernova / Acceleration Probe: An Overview	M. Levi (LBNL)
The SNAP Telescope	M. Lampton (UCB)
SNAP: An Integral Field Spectrograph for Supernova Identification	R. Malina (Marseille,INSU), A. Ealet
Supernova / Acceleration Probe: GigaCAM - A Billion Pixel Imager	C. Bebek (LBNL)
Supernova / Acceleration Probe: Cosmology with Type Ia Supernovae	A. Kim (LBNL)
Supernova / Acceleration Probe: Education and Outreach	S. Deustua (LBNL)

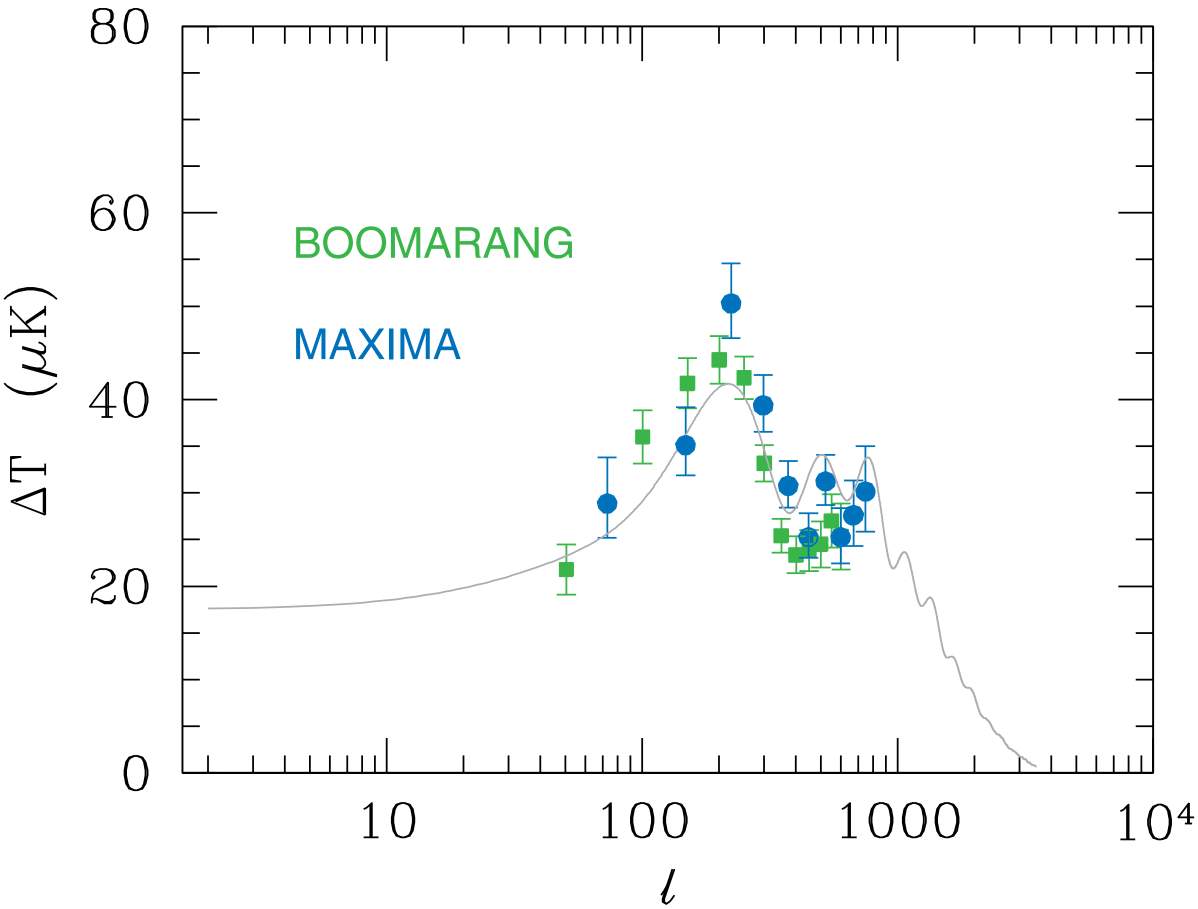
Expansion History of the Universe




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

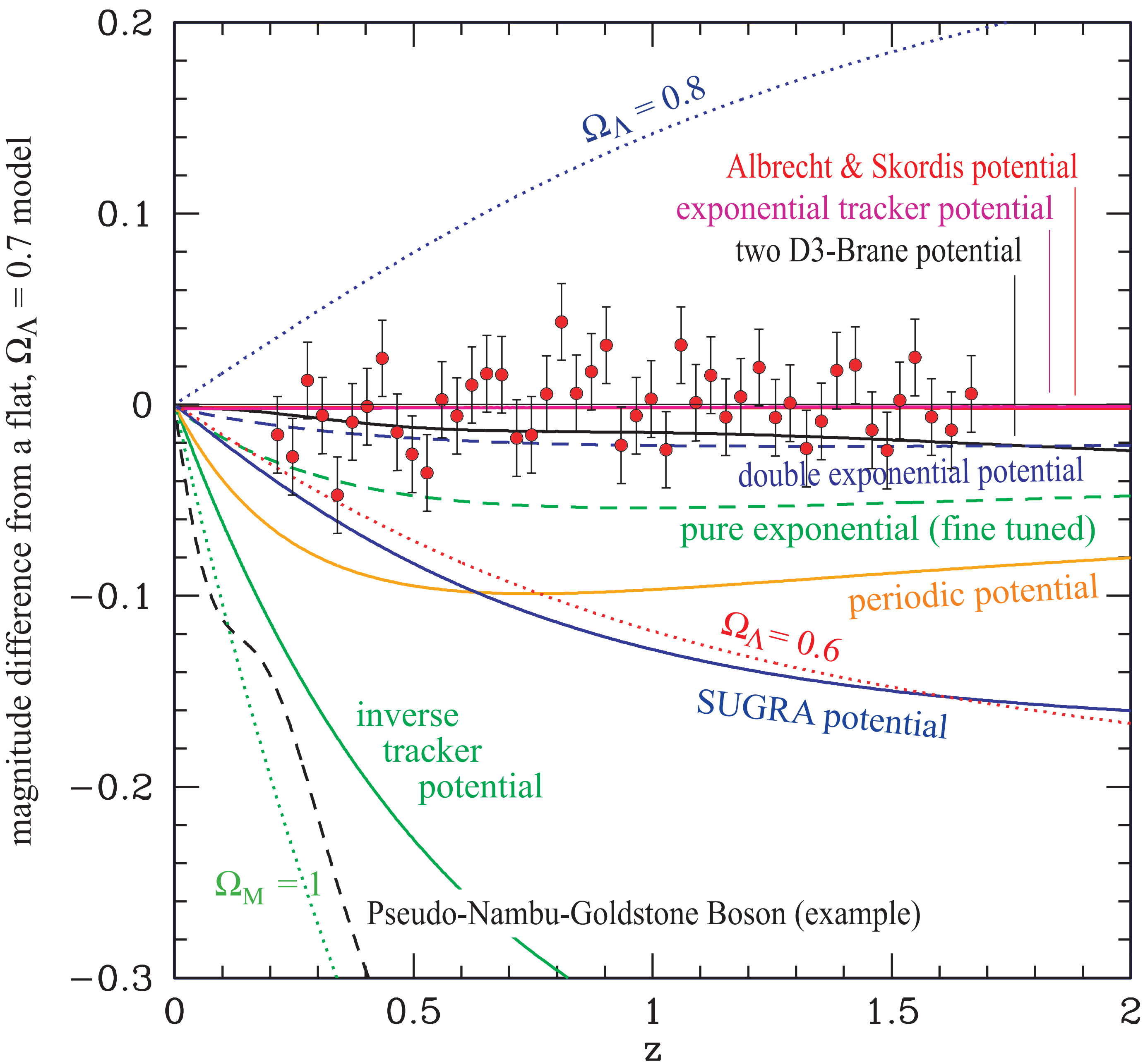
CMB data before BOOMARANG and MAXIMA





SNAP SuperNova Acceleration Probe

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



based on

Weller & Albrecht (2001)

Expansion History of the Universe