SNAP at Fermilab: Context and Hardware R&D

SNAP Overview

- Overview of Dark Energy
- Collaboration
- Dark Energy Science / Surveys

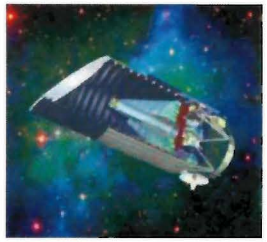
FNAL Contributions and Opportunities

- CCDs
- Flash Memory
- Calibration
- Simulations
- Data Management & Software *
- Science

Resources

Delta 4 Payload

Steve Kent June 18, 2008



Present-day universe is dominated by "dark energy"

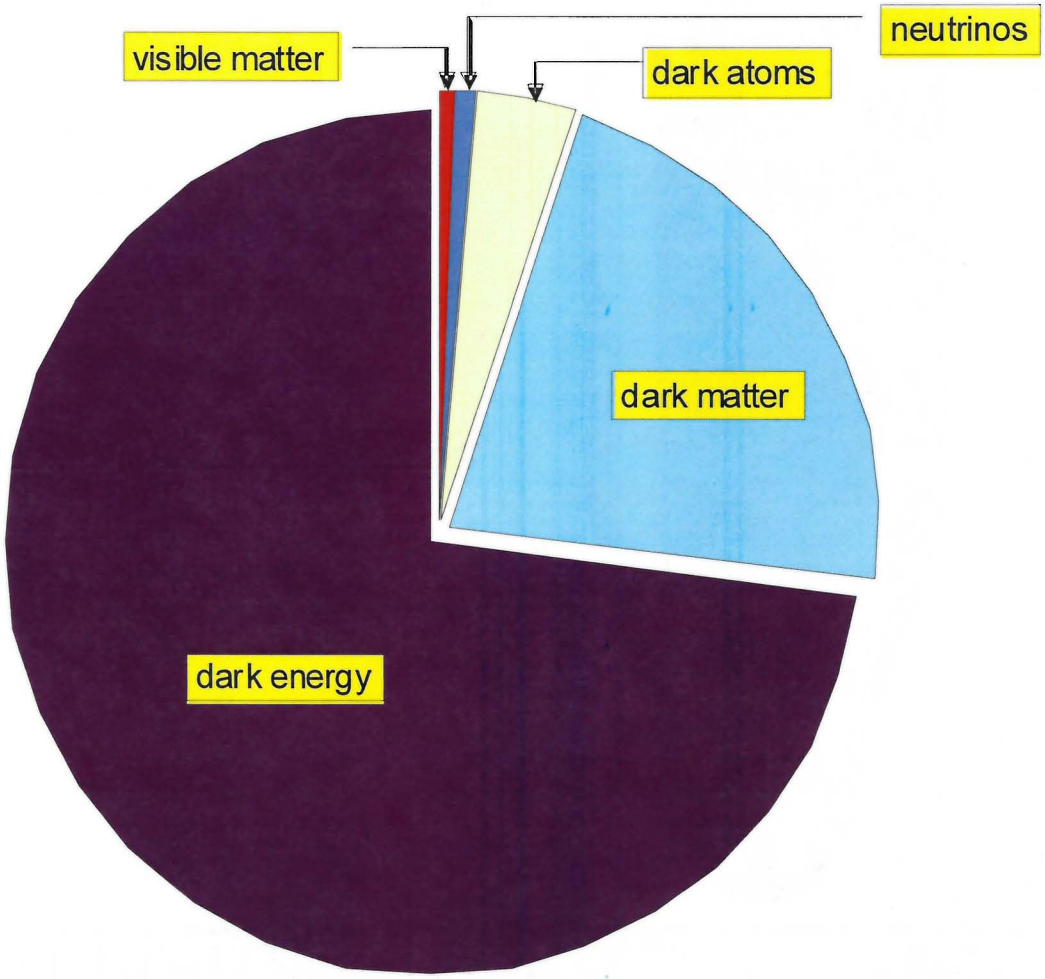
Dark Energy:

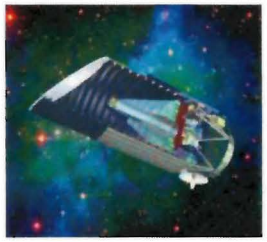
$P \sim -\rho$

Expansion of universe is accelerating

We don't know what it is.
We don't know why it is becoming dominant right now.

It's not going away





What does it mean to "measure Dark Energy"?

Dark Energy equation of state: $P_{DE} = w\rho_{DE}$

Goal: find w(z)

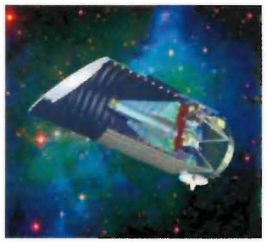
w = -1 "Lambda"

Equation of motion: $d^2R/dt^2 = -(4\pi G/3)(\rho_{tot}+3w\rho_{DE})$

w < -1/3 acceleration

Growth of structure: $d^2D/dt^2 = F(D,w,\rho,R,dR/dt)$

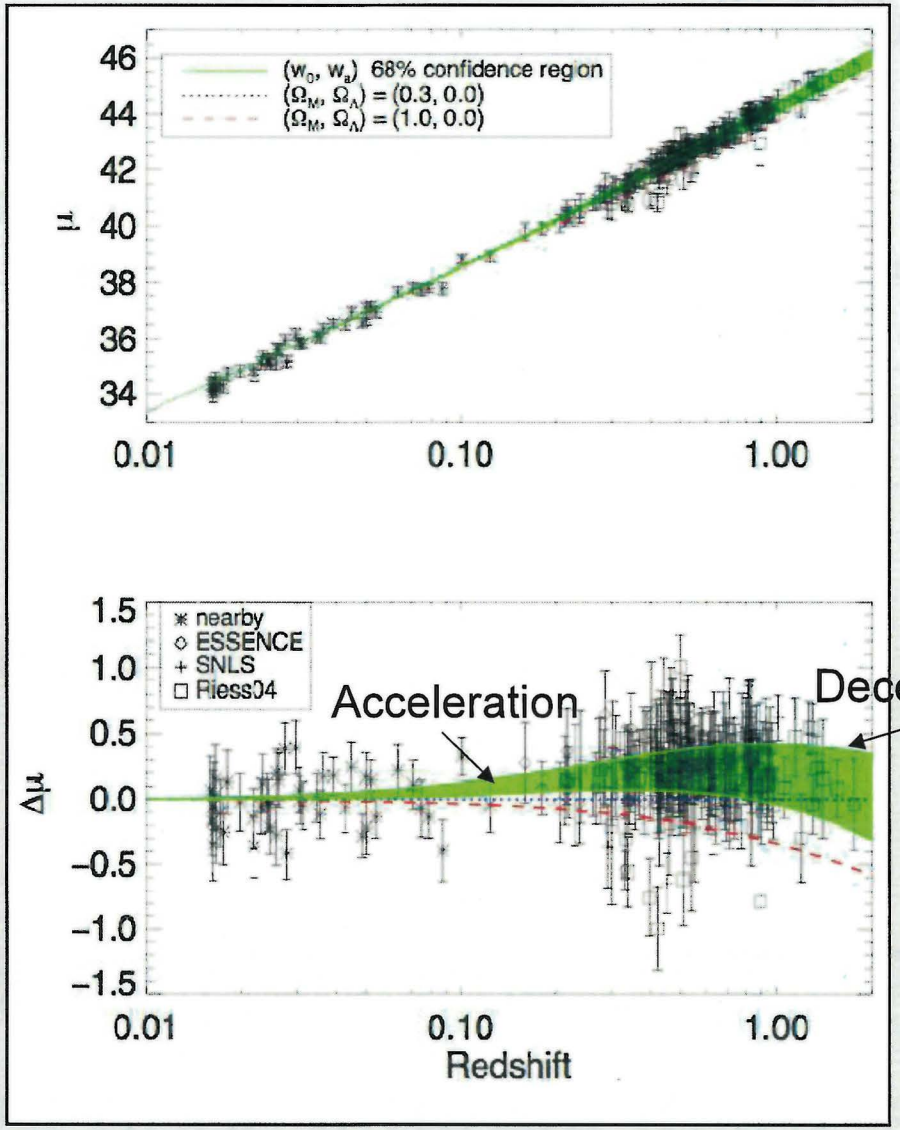
D measures density *contrast*



Supernovae measure acceleration

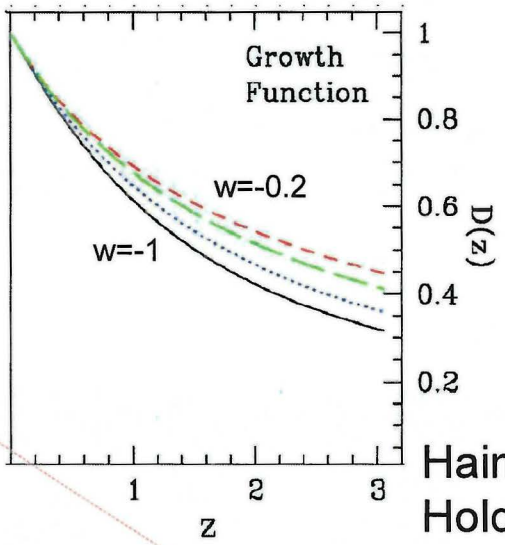
Global SNIa Hubble Diagram

Hamuy 1996a,b
Riess 1998
Perlmutter 1999
Riess 1999
Riess 2001
Tonry 2003
Knop 2003
Barris 2004
Riess 2004
Clochiatti 2005
Astier 2006
Jha 2006

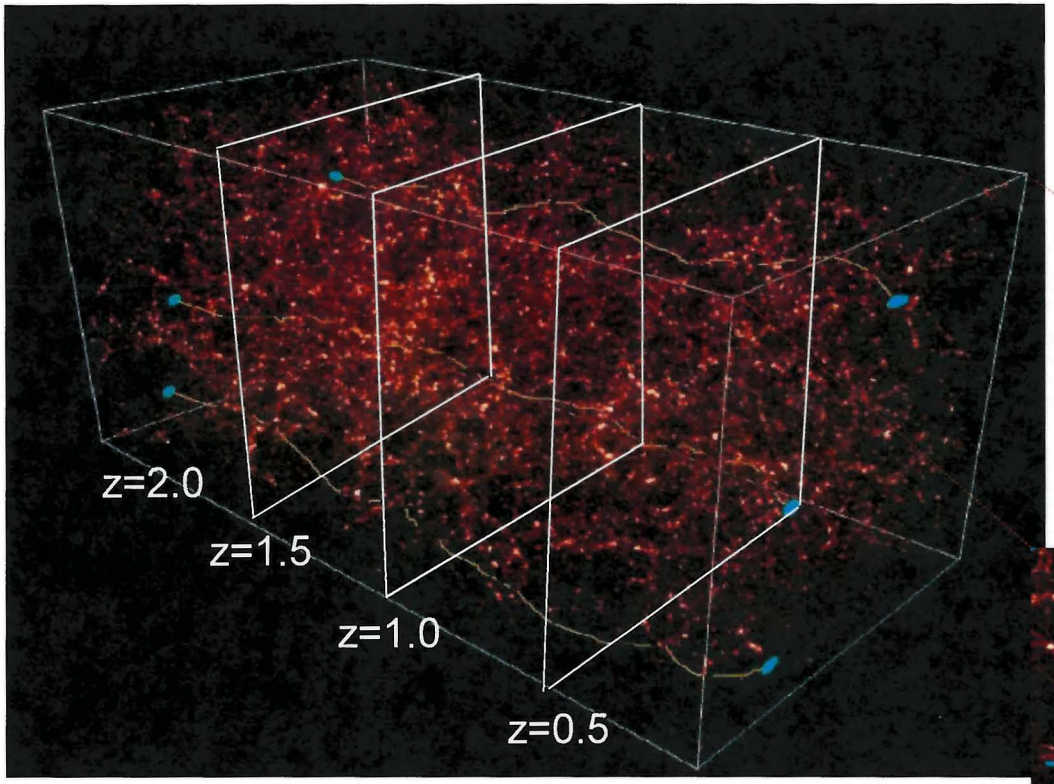


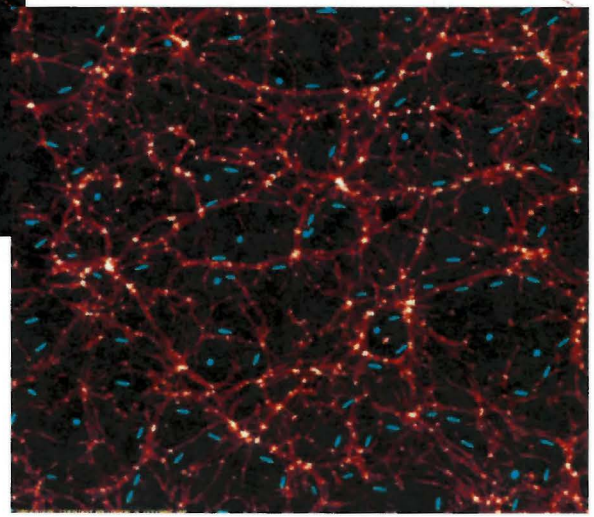
Supernovae are "standard candles"

Weak lensing measures "growth of structure"



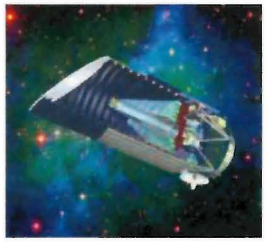
Haiman, Mohr, Holder





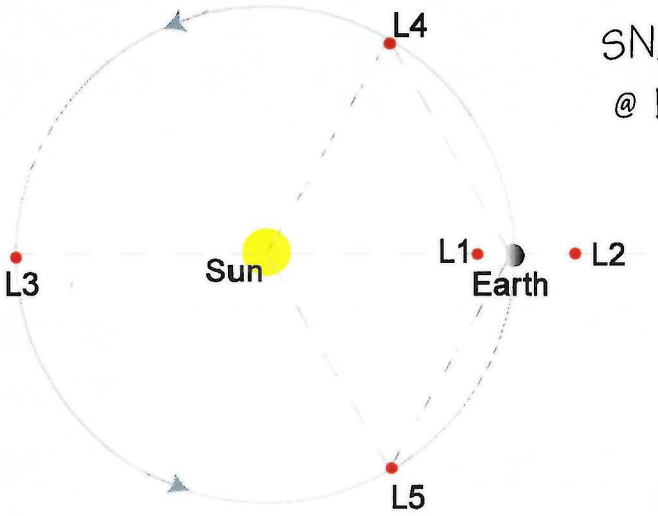
Use distant galaxies to perform

"tomography" of intervening structure.



SNAP

SNAP - the **S**uper**N**ova **A**cceleration **P**robe - is a proposed space observatory designed to measure the expansion of the Universe and to determine the nature of the mysterious Dark Energy that is accelerating this expansion.



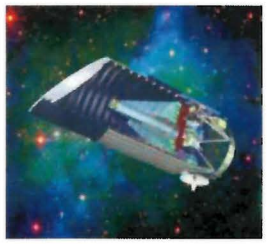
SNAP
@ L2

SNAP is being proposed as part of the Joint Dark Energy Mission (JDEM), a cooperative venture between NASA and DOE. If selected it will be launched by middle of next decade.

SNAP Collaboration

- SNAP Collaboration has ~140 scientists from

LBNL
Berkeley
Caltech
FNAL
Indiana U.
IN2P3 – Paris/Marseille
JPL
LAM
U. Michigan
U. Penn.
U. Stockholm
SLAC
STSI
Yale

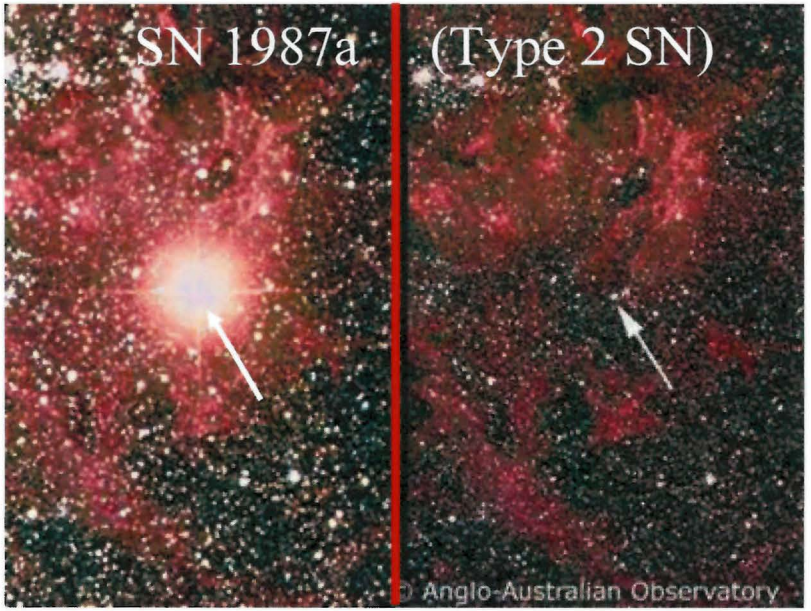


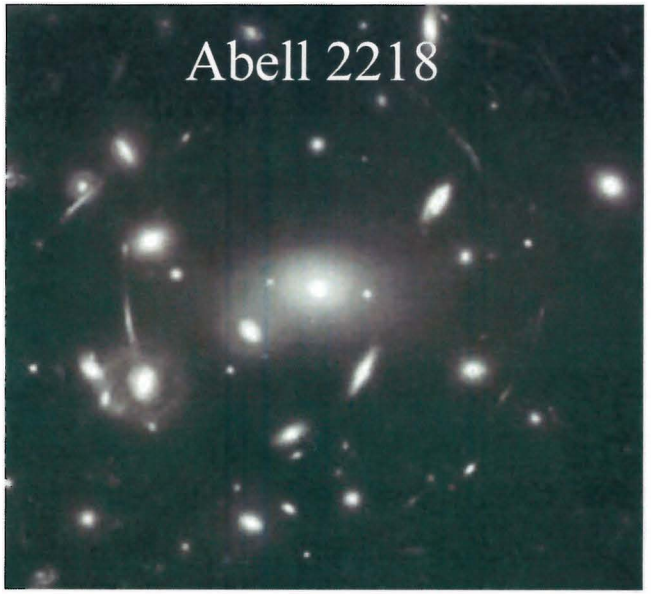
FNAL/SNAP Group

- Fermilab joined the SNAP Collaboration in 2004.
- Scientific Membership (2004-2007)
  - Allam, Annis, DeJongh, Dodelson, Diehl, Frieman, Hui, Kent, Limon, Marriner, Lin, Peoples, Scarpine, Stebbins, Stoughton, Tucker, & Wester are members of the collaboration.
  - A few have dropped off the map but are still listed in name.
  - Also, some scientists show interest and even contribute in their limited available time but aren't listed.
  - ~7 scientists are currently investing significant time

SNAP Surveys (as presented to BEPAC)

- SuperNova Survey
  - Repeated scans of 15 sq degrees for 22 months.
  - identify, then follow-up SN1a to z=1.7 with on-board spectograph
- Weak Lensing Survey
  - 1000 sq deg for 12 months
  - Also allows study of clusters and large scale structure
  - broad scientific appeal to astronomers





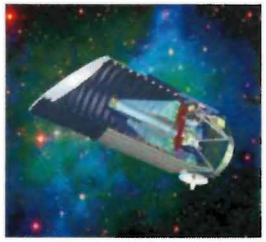
Beyond Einstein Program Assessment Committee

- Announcement of encouraging news on September 5, 2007

WASHINGTON -- NASA and the U.S. Department of Energy should pursue the Joint Dark Energy Mission (JDEM) as the first mission in the "Beyond Einstein" program, according to a new report from the National Research Council. Beyond Einstein is NASA's research roadmap for five proposed mission areas to study the most compelling questions at the intersection of physics and astronomy…

Current Status of JDEM

- Concept Study Report was due at NASA in May 2008
  - Replaced by Request for Information
- Announcement of Opportunity will be issued by NASA
  - Draft in ~Sept. 2008
  - Formal AO ~Dec. 2008
  - 90 days to respond
  - Cost cap of $600 million (excluding launch)
  - Up to $200 million of that from DOE

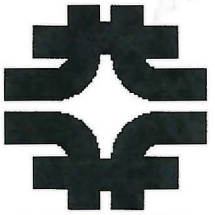


FNAL Contributions

Current & Future Accomplishments, Plans, and Opportunities

- CCDs
- Flash memory
- Calibration
- Simulations
- Data Management [Erik Gottschalk]
- Science

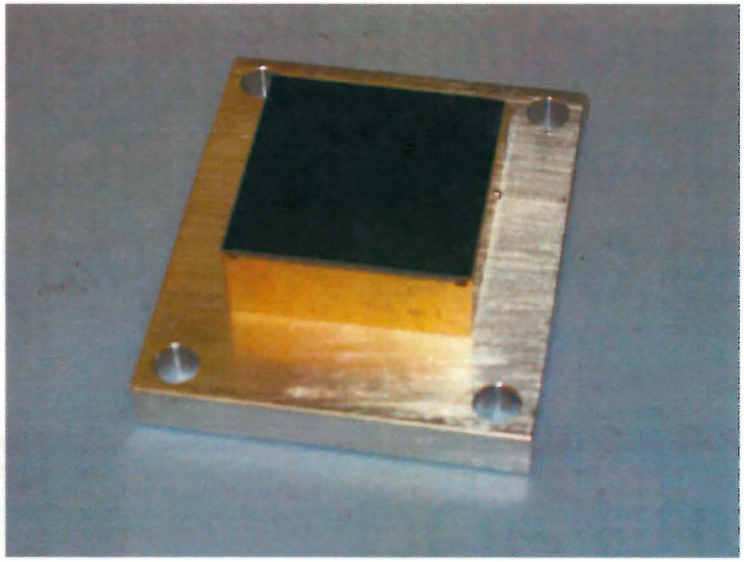
DOE Funded Proposals

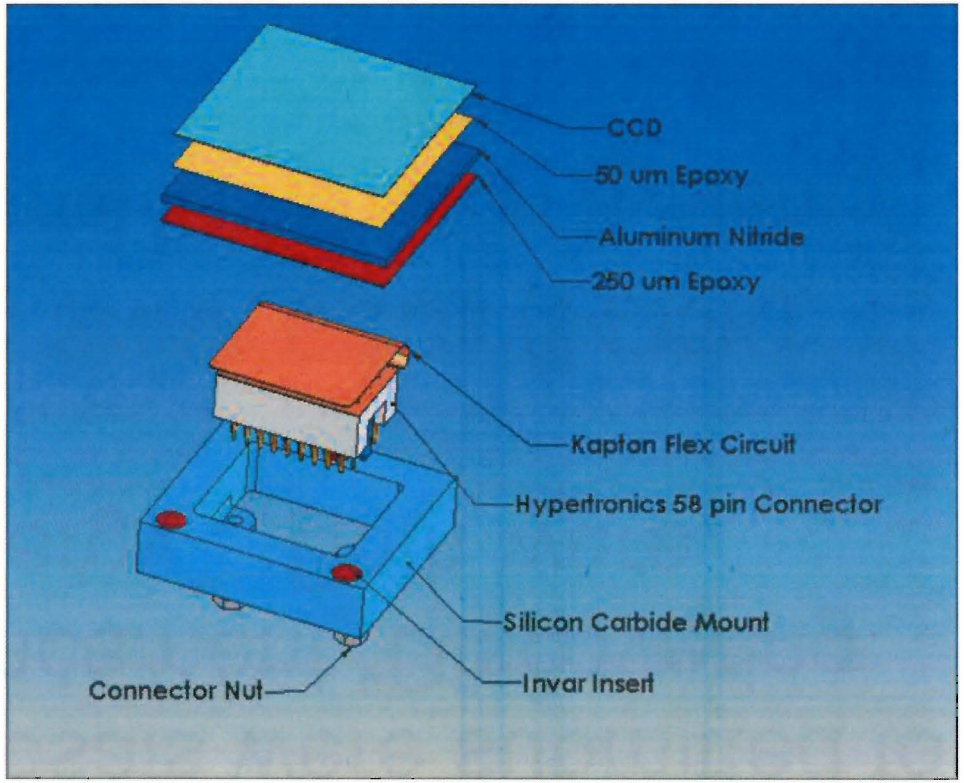


- Two SNAP R&D proposals were submitted to DOE Program Announcement "Discovering the Nature of Dark Energy". Both were accepted.
  - Packaging and Testing SNAP CCDs ($435K)
  - Testing the SNAP Internal Illumination System ($154K)

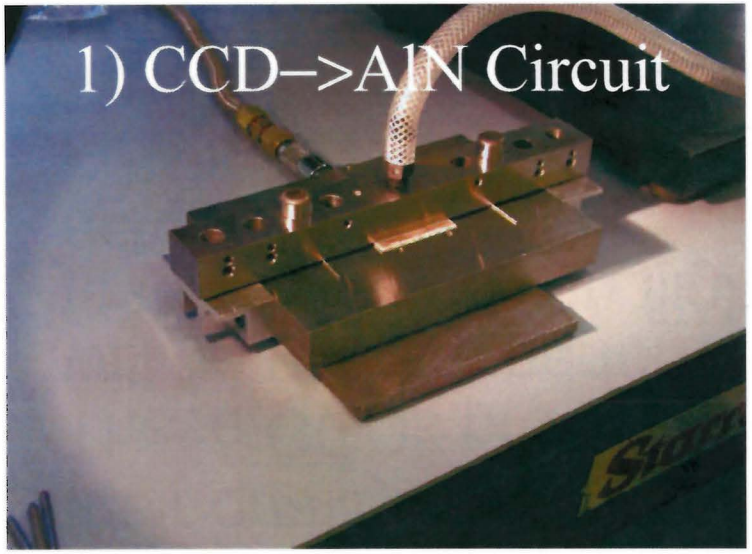
Packaging SNAP CCDs

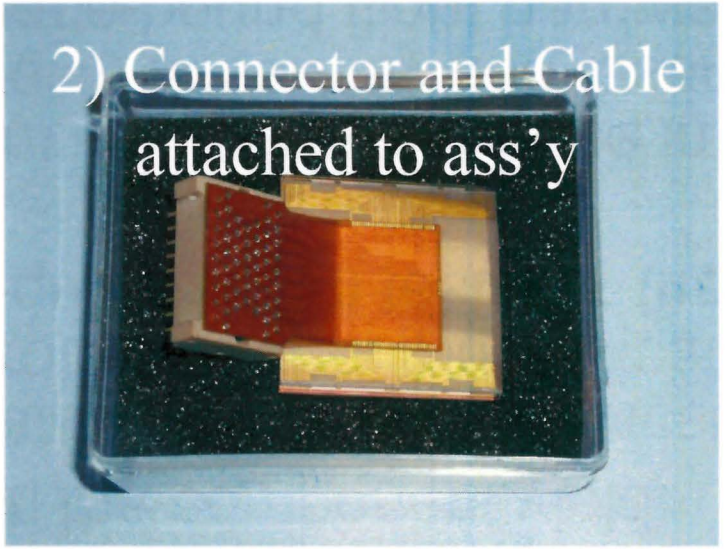
- Ongoing R&D
- The Prototype 4-side-buttable package was developed by our Yale Collaborators in 2005-2008.

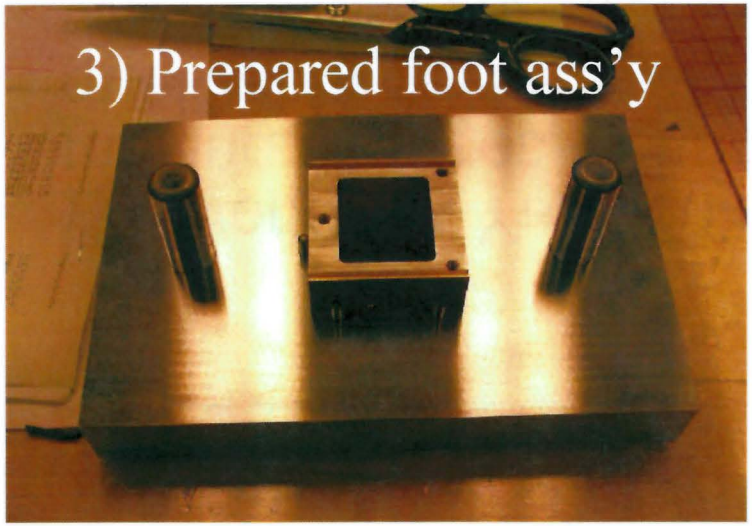


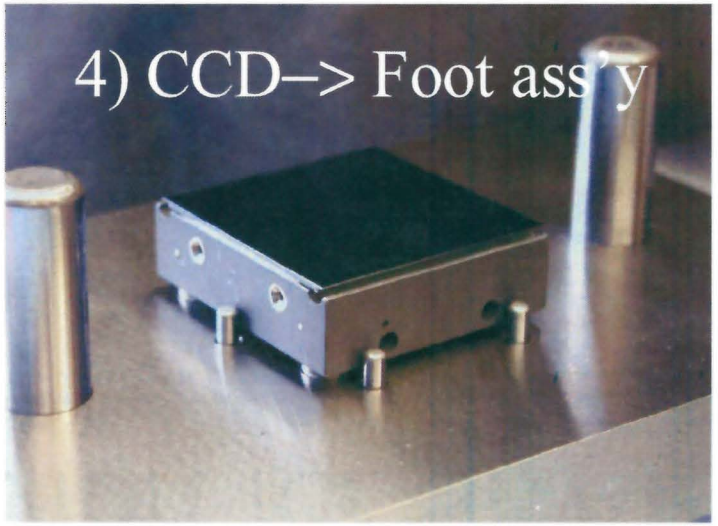


Yale Packaging Procedure

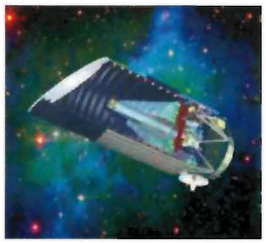




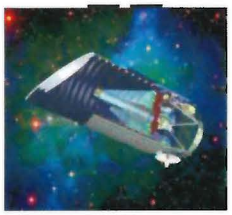




Photos from C. Baltay



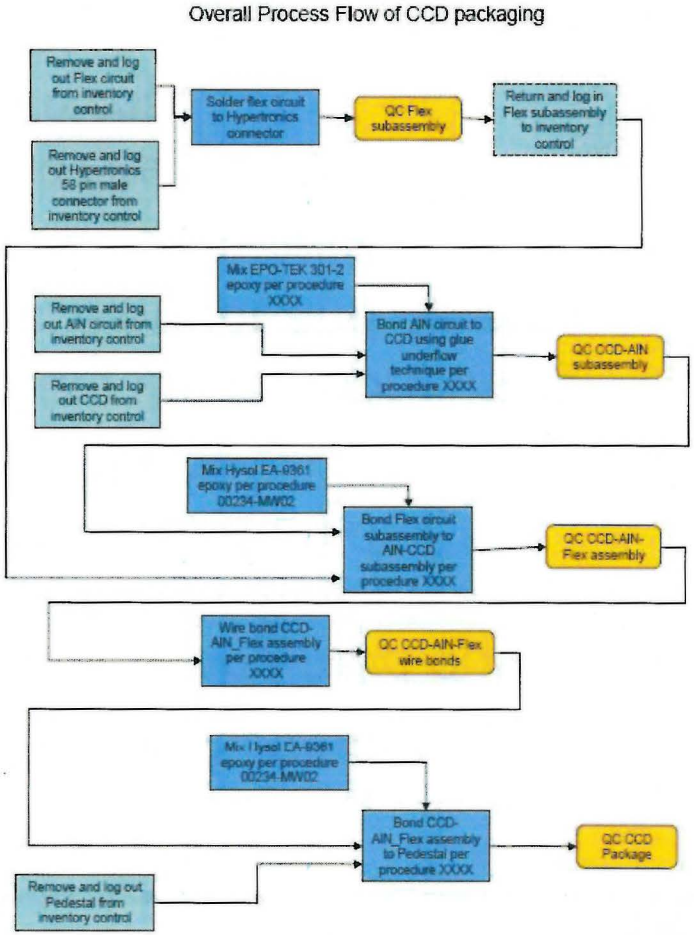
CCD R&D Effort for SNAP

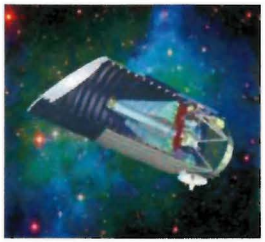


- We work with Yale to finish the package design, making changes as necessary for producing space-qualifiable devices.
- We produce and test a number of devices to check their quality, and establish the component yield.
- These CCDs provide a sample of working devices that will be used to perform prototype space-qualification tests and to design flight-qualification tests for the actual flight devices.
- Finally, it will provide Fermilab with experience in the high-level of quality control in assembly and testing required for producing space-bound flight hardware.

Space Qualified Packaging & Testing

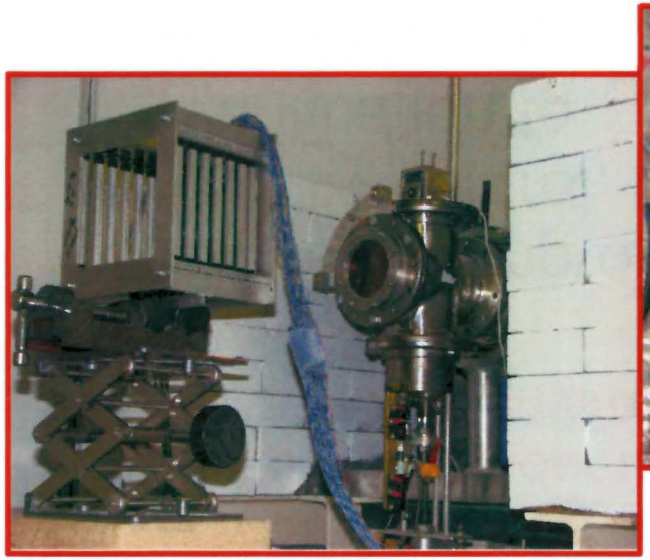
- Achieve NASA Technical Readiness Level 6:
  - System/subsystem model or prototype demonstration in a relevant environment (Ground or Space)
- Requires improvements in quality control, monitoring, and verification to
  - Infrastructure,
  - Procedures,
  - Technicians to be trained in NASA standards.





Flash Memory radiation tests

- Flash memory is desirable: compact, low power, but …
- Radiation causes: single event effects up to catastrophic damage



- Build, test, and read out cards using different mass memory vendors and technologies.
- Irradiate the memory using an accelerator and determine when the part fails.
  - Indiana cyclotron (200 MeV protons)
  - LBL cyclotron (heavy ions)

IEEE paper 2004

Proton Irradiation Effects on 2Gb Flash Memory

Results

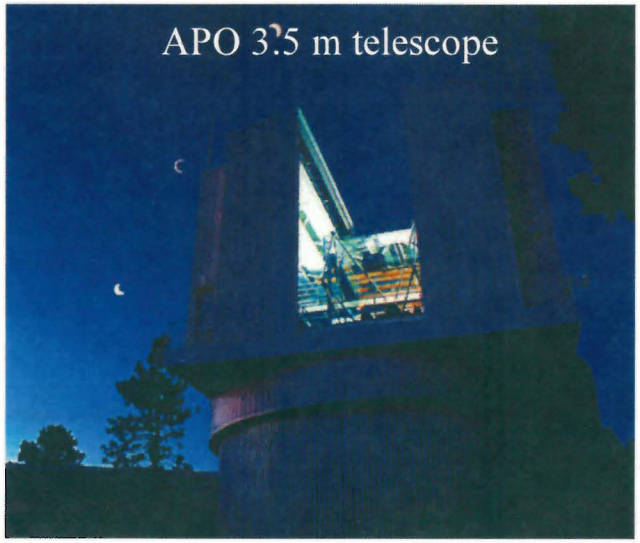
- Single Event Upsets observed
- 2 Gbyte devices (90 nm) fails at 15-25 krad
- 4-8 Gbyte devices (65 nm) fail at 25-50 krad

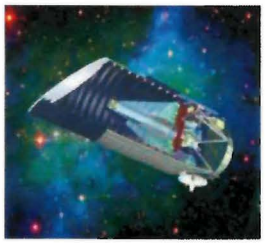
SNAP Calibration

A small but important effort,

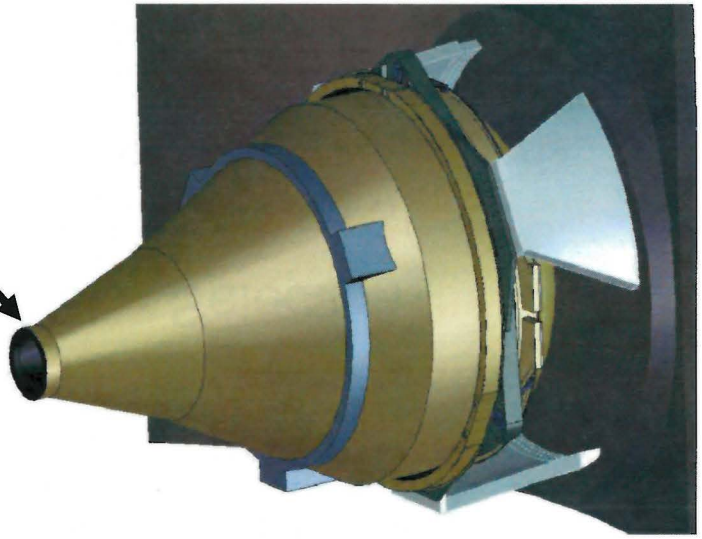
We want to measure the brightness of SN1a to 2%.
We want to measure the shapes of objects to 0.01%.

- Work with calib. working group
  - Develop calib. plan
  - Define onboard hardware
- Standard Star Selection
  - Target selection from SDSS, then follow-up with other telescopes.
- Requirements analysis
  - Flowdown from top level req.
- Calibration Planning
  - Calibration pipeline
- Tiger Team Participation
  - CSR/RFI preparation





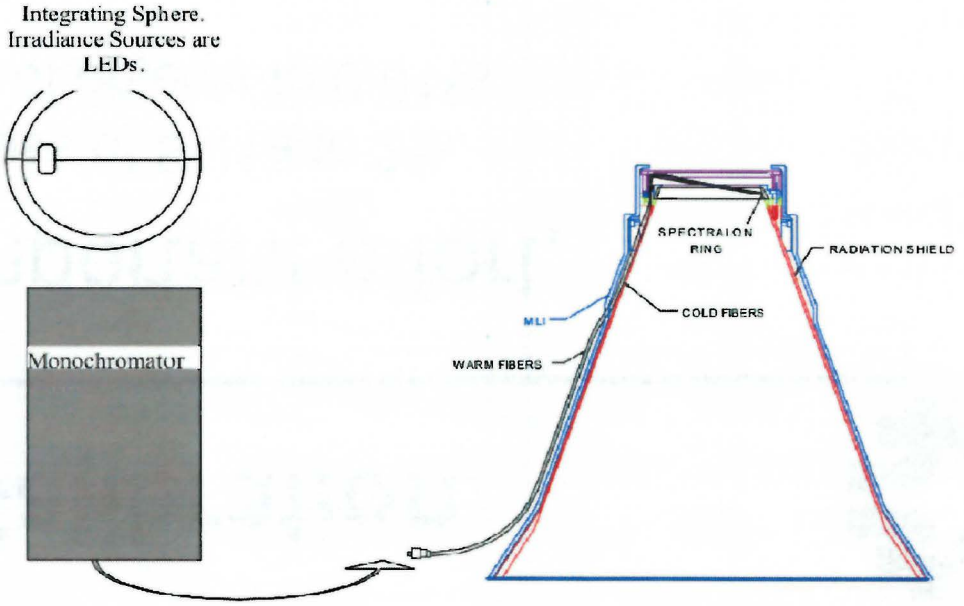
Illumination System R&D



Goals:

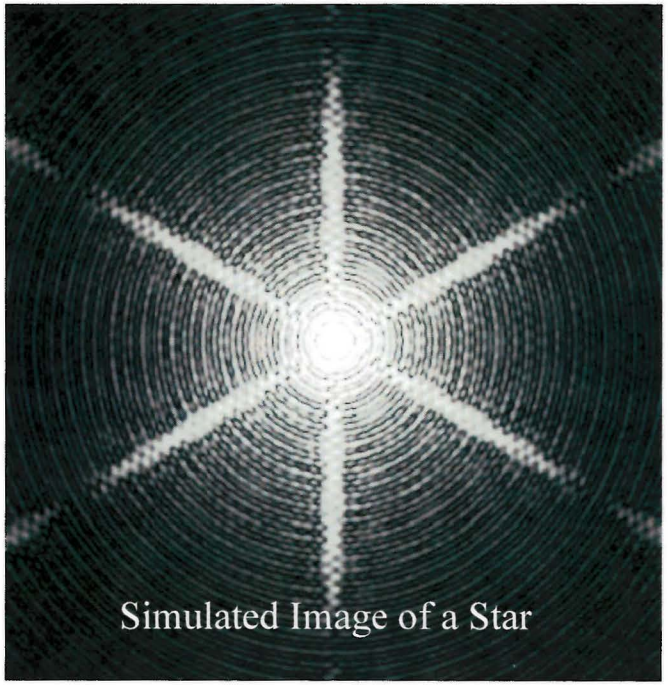
1. Construct prototype of R.O.F. and illumination system
2. Test flatfielding uniformity
3. Test filter calibration

Joint with SSL, IU, STScI

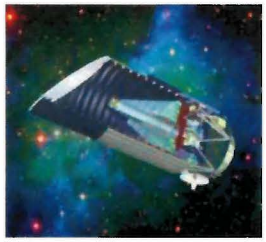


Simulations

- We are performing pixel level simulations of SNAP Data
  - Leveraged with development of DES simulations
- Software Management & Testing
- Testing of data compression algorithms

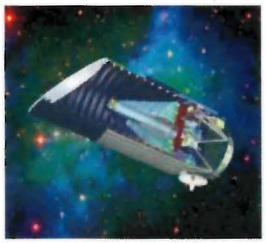


Simulated Image of a Star



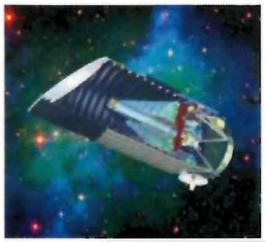
Data Management & Software

- Areas
  - Software development
  - **Science Operations Center**
  - Data Archive
- Size of effort
  - Long-term average of 35-40 FTEs over entire collaboration for all of above activities; half of effort at FNAL?
  - For comparison, SDSS data management at Fermilab was ~18 FTE at peak



Science

- Define Science Requirements
  - FNAL Theorists Early "Victory"
    - They understood the importance of the weak- lensing measurement
    - and convinced the Collaboration to increase the wide area survey from 300 to 1000 square degrees.
  - Examples: # of different filters, required point spread function
- Turn those into Technical Requirements
  - Examples: QE, readout time …

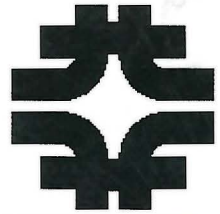


Resources (not loaded)

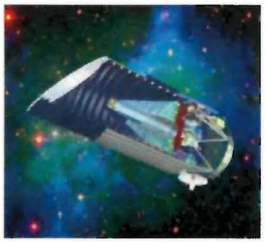
	FY08		FY09			
	M&S	FTE	M&S	FTE		
Electronics/Flash Memory	$30k	2	$10k	0.5		
Calibration	$8k	1.0	$154k	1.5		
Simulations	$0k	1.0	$0k	1		
CCD's	$60k	2.5	$435k	3		
Software/Data Management		0.5				
Science	0	0	0	0		
Total One Year Costs	$98k	7	$599k	6+		

- Estimates don't include the wider-scope plans for Data Management Software.

Summary



- BEPAC announcement: JDEM is 1st priority
- SNAP is a leading competitor for the JDEM.
- FNAL is a strong collaborator on SNAP
  - Since 2004 we have been making valuable contributions in a variety of areas
  - significant potential to grow.



End of Talk

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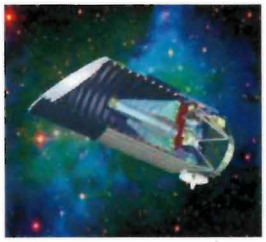
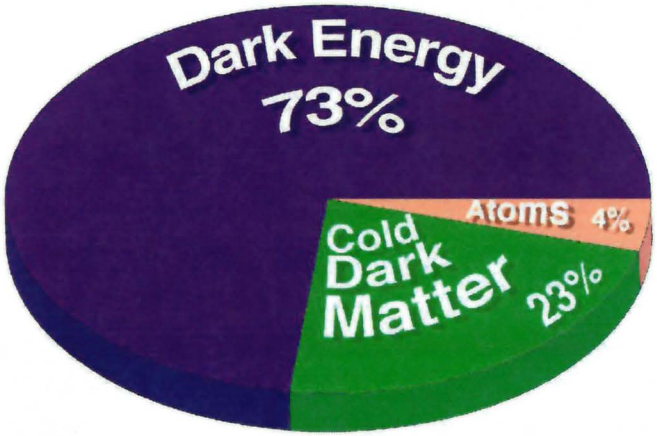
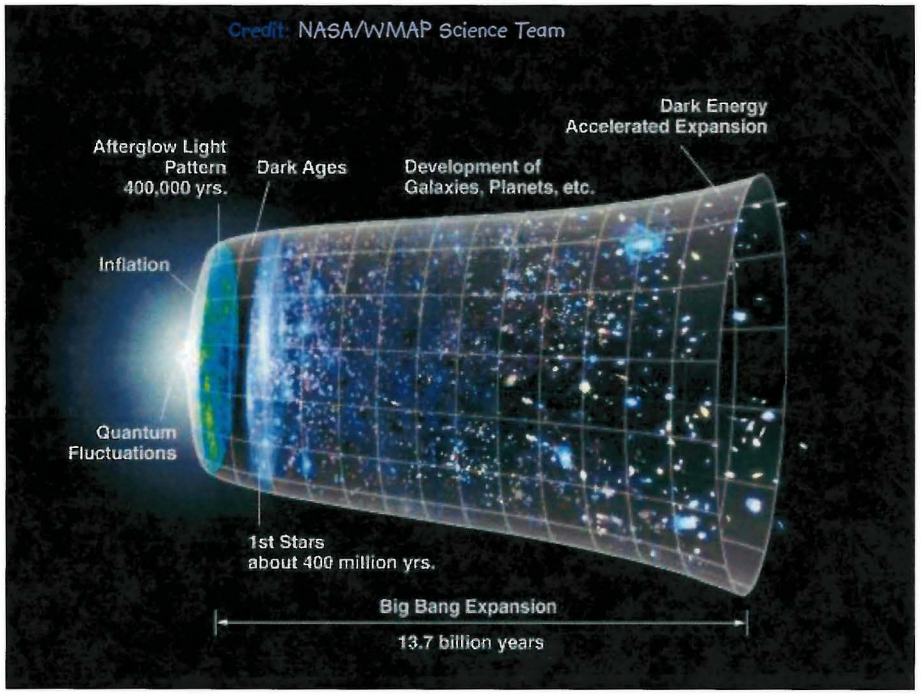


Science: Big Picture

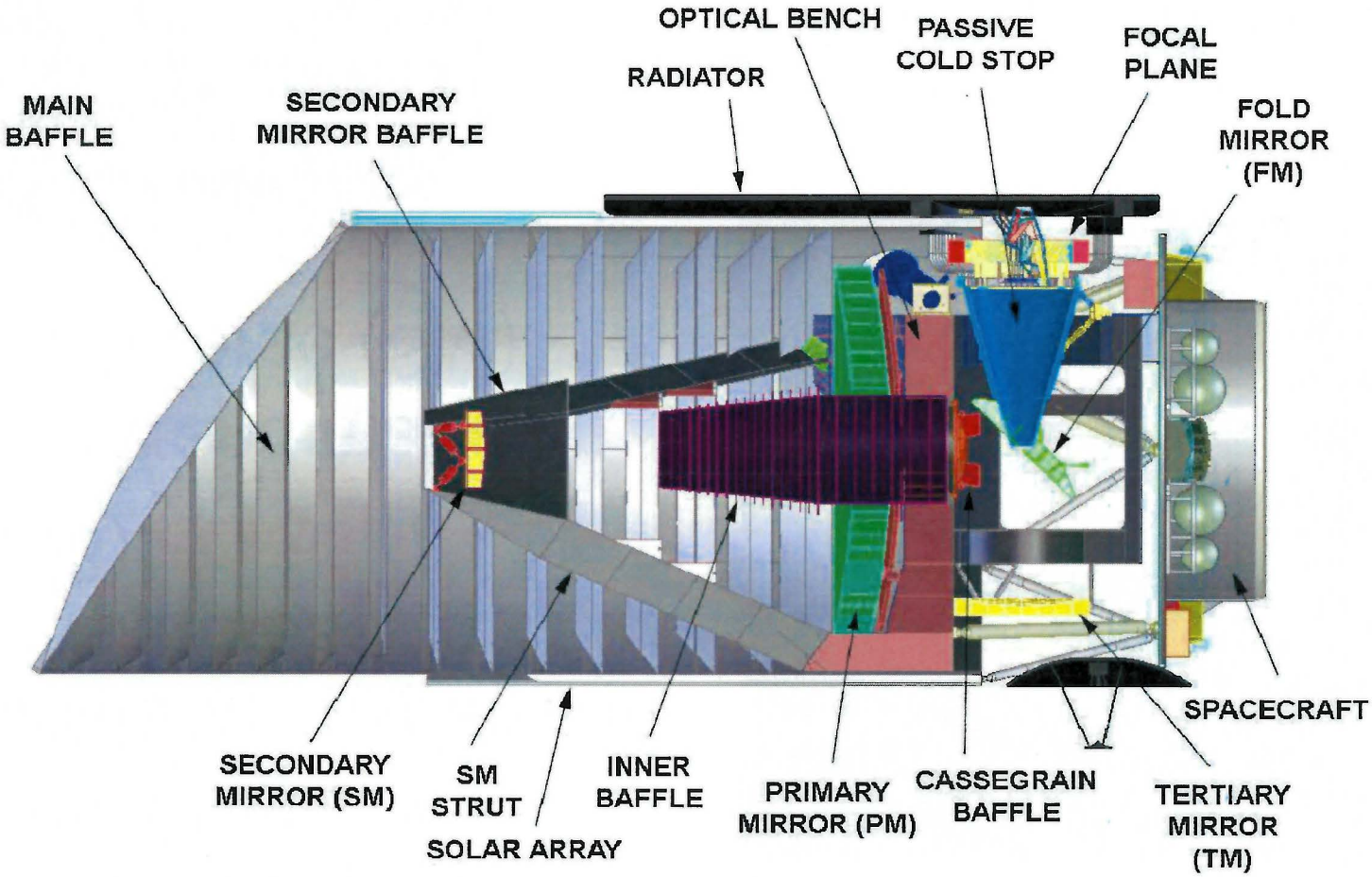
- Studies if SN1a indicate the expansion rate is increasing (1998).
- Energy and matter in the Universe (SM)



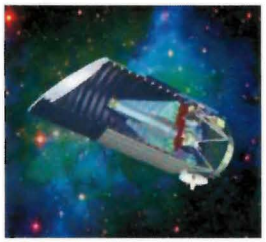


- We seek to understand the details of expansion history.

The SNAP Instrument

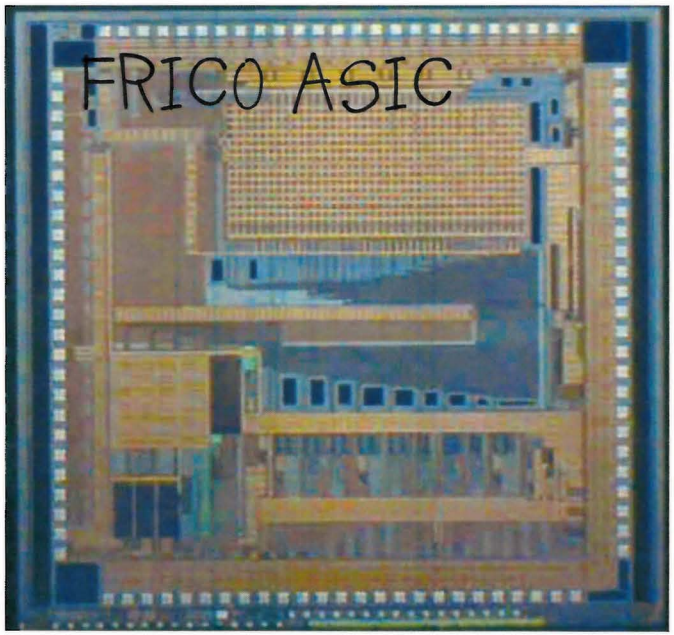


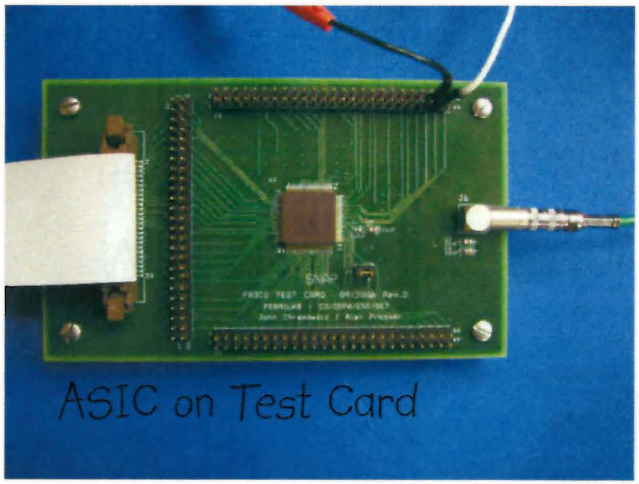
Is a telescope



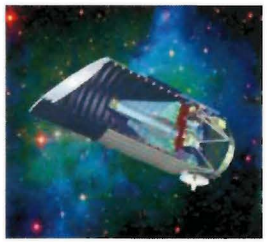
FRIC Status + Plans

- Fermilab started design of an ASIC intended for readout of the Raytheon NIR detector and as a support device (Low-voltage regulated power) for CCDs & the both Raytheon and Rockwell NIR detectors.
- Regulated power circuit finished in (2006)
- Received ~40 parts including 5 that are packaged.
  - Some were sent to U Mich for their Raytheon NIR test stand.
  - Remaining work on FRIC0 is to test the noise and the stability of the voltage regulation at operating (cold) temperature
- A default "downselect" to Teledyne (Rockwell) instead of Raytheon for NIR detectors has occurred.



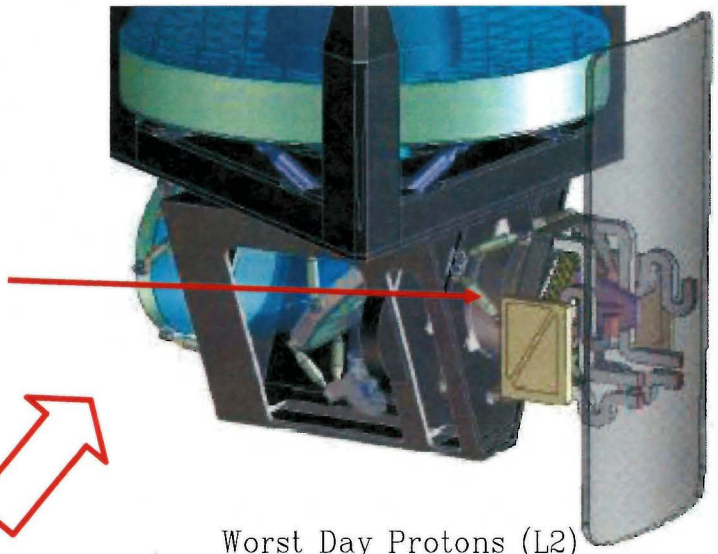


The downselect signals this is ending.

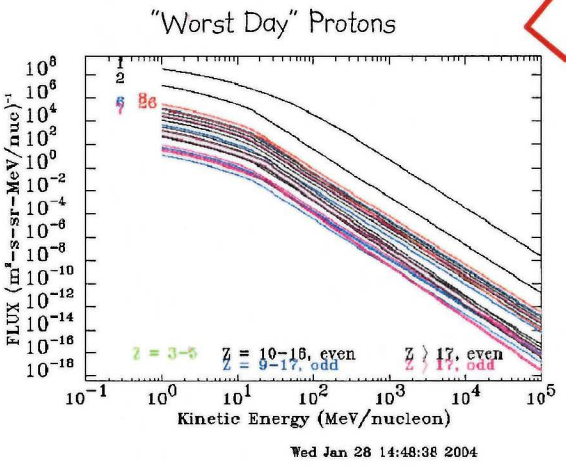


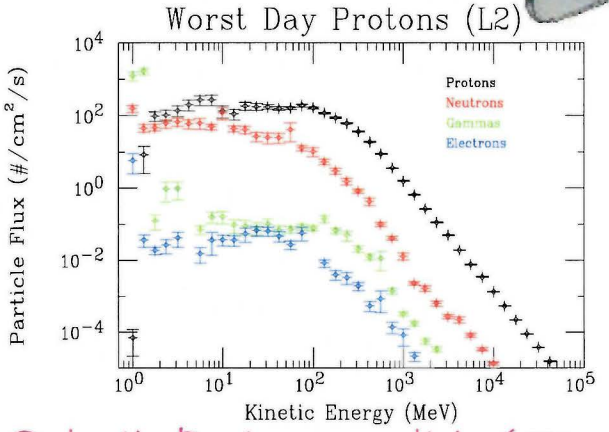
Radiation Shield MC

- Shield from cosmic rays, stray visible light, stray heat
- early design work

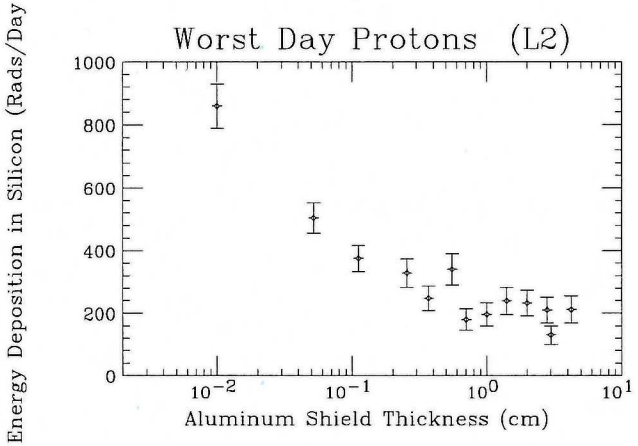


MARS Simulation of near focal plane material





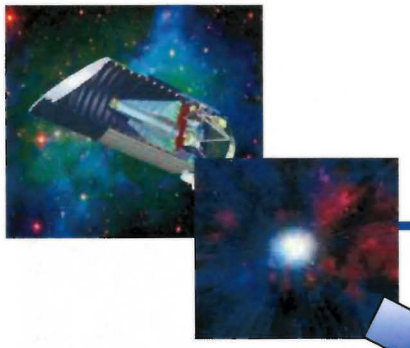
¾ cm Al preferred



Galactic Protons result in 6.78+-0.45 Rads/Yr.

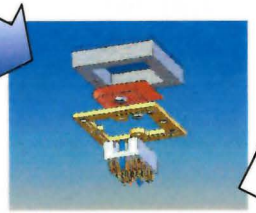
"Worst Day" Protons results in 179+-34 Rads/day for this very rare occurrence

Data Acquisition Electronics Overview



ICU controls readout, allocation of mass memory, etc

80



Focal Plane Detectors + FEE

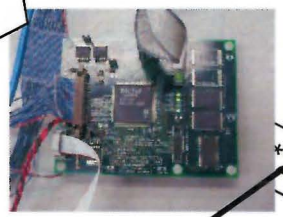
*2Gb/s

"Slice" Modules

2

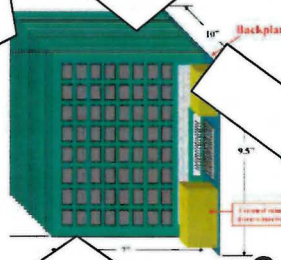
Data compression
Data management
Data formatting
Interface to electronics modules

80



*2Gb/s

*50Mb/s



Slice Crate

2

*300Mb/s

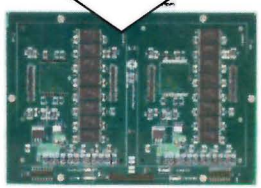
Telemetry

2

*8Gb/s

*300Mb/s

80

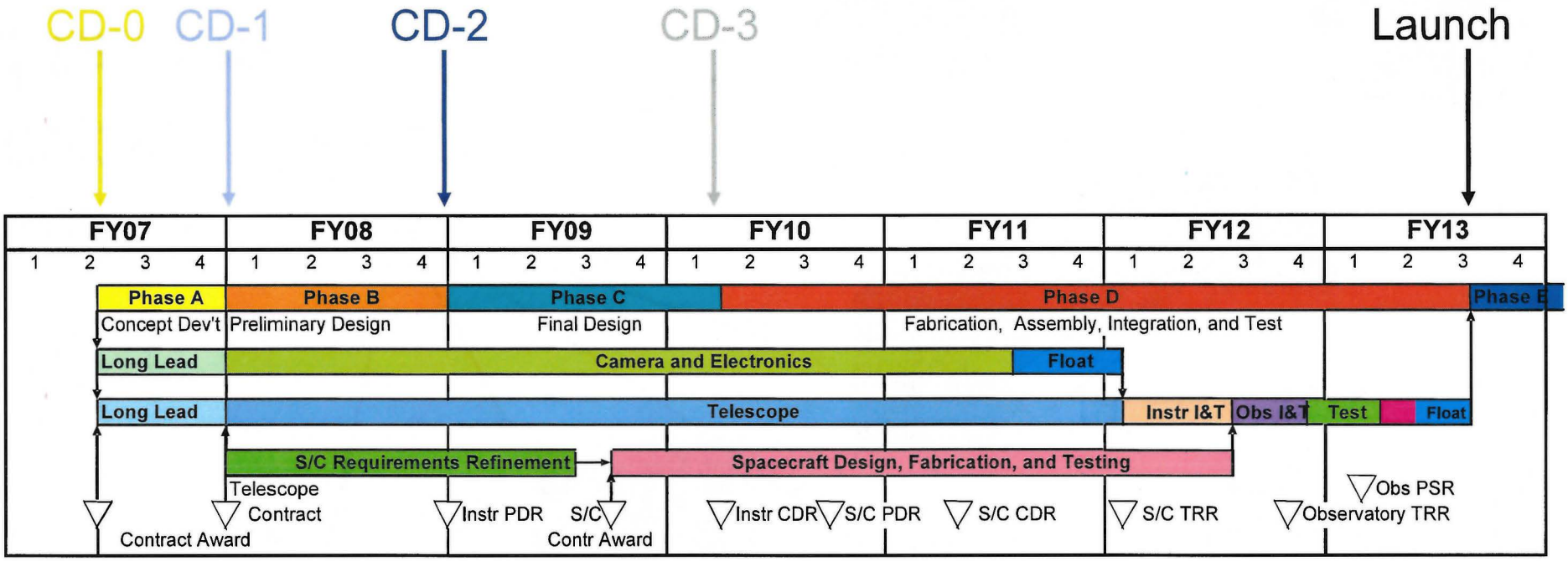


Memory Modules

* Peak data rates displayed. Data comes in bursts with a 10% duty cycle.

Fermilab electronic design and testing contributions since 2004

Technically Driven Schedule



	FY07	FY08	FY09	FY10	FY11	FY12	FY13
Mile-stones	Select SNAP Concept Dev't CD-0 Long Lead Procurements	Prelim Design CD-1 Telescope Contract	Final Design CD-2 Instrument PDR Spacecraft Contract	Fabrication CD-3 Instrument CDR Spacecraft PDR	Fabrication Camera I&T Spacecraft CDR	Integration & Test Telescope I&T Observatory I&T Spacecraft I&T	Launch Begin Operations

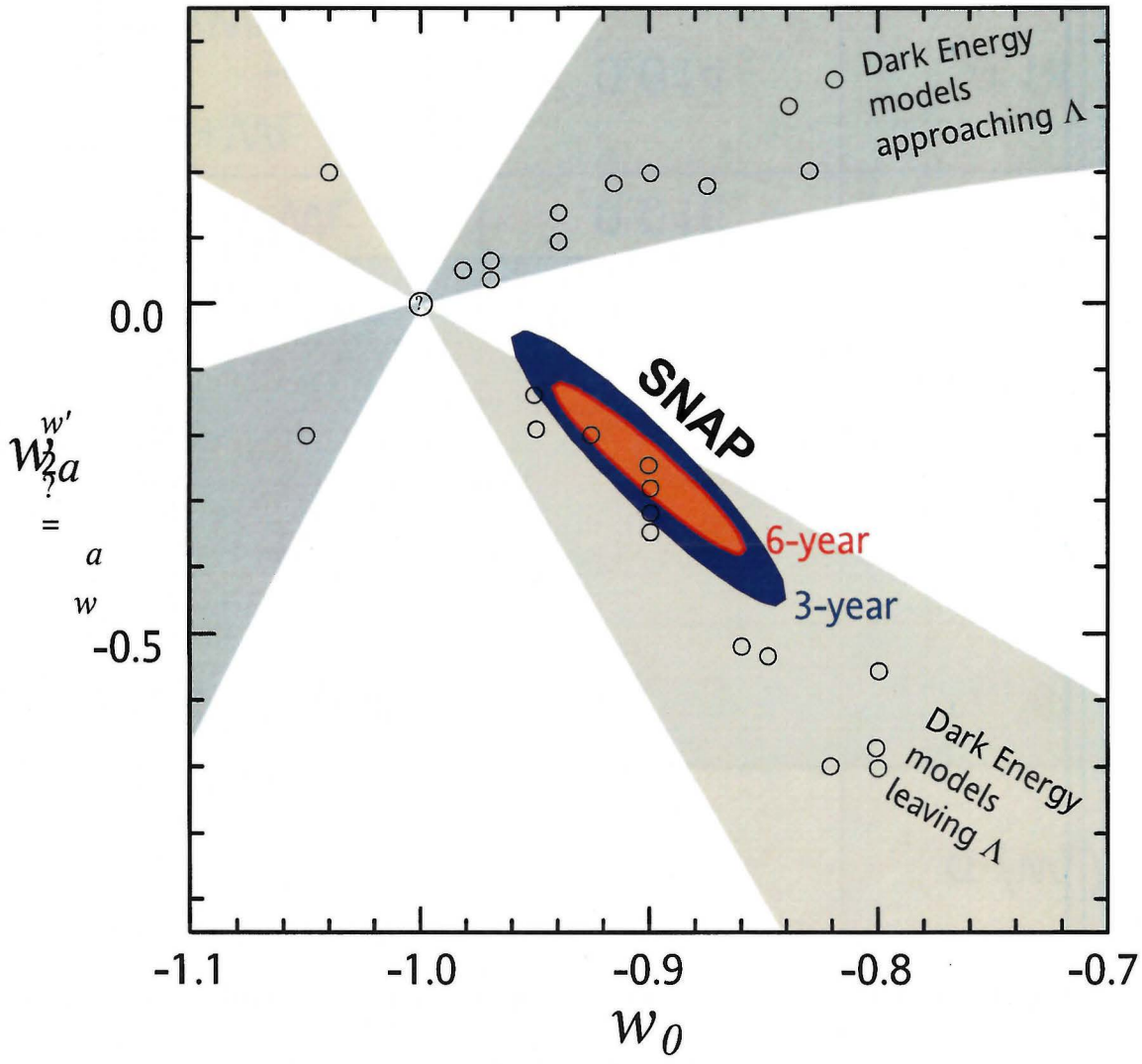
As of September 2006

SNAP

	Uncertainties for scenario with…	$\sigma(w_p)$	$\sigma(w_a)$	Merit
SNAP Alone (3 years)	SN (flat, Ω_m=0.3)	0.020	0.36	134
	SN (flat, Ω_m=0.25)	0.018	0.32	181
	SN+WL (flat, Ω_m=0.3)	0.021	0.24	203
	SN+WL	0.029	0.24	146
SNAP + Planck (3 years)	SN+WL	0.016	0.18	371
	SN+WL + flat +gnd (WL+BAO)	0.014	0.14	555
SNAP Extended (6 years)	SN+WL (extendedmission)+Planck +gnd(WL+BAO)	0.012	0.10	911

ML 6/2006

SNAP


Dark Energy
models
approaching Λ
SNAP
6-year
3-year
Dark Energy
models
leaving Λ
0.0
-0.5
-1.1
-1.0
-0.9
-0.8
-0.7
w_0
w_a