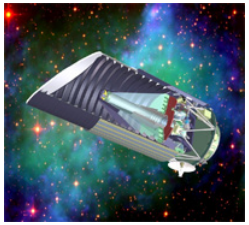


SNAP at Fermilab

SNAP Overview

- Collaboration
- Dark Energy Science / Surveys

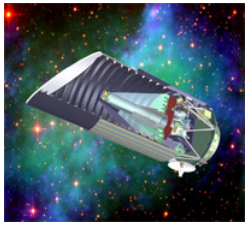
FNAL Contributions and Opportunities

- CCDs
- Front End Electronics
- Data Acquisition Electronics (SLICE)
- Focal Plane Assembly *
- Calibration
- Data Management & Software *
- Science

Resources

Delta 4 Payload

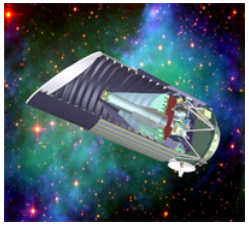
Tom Diehl Sept. 26, 2007



Beyond Einstein Program Assessment Committee

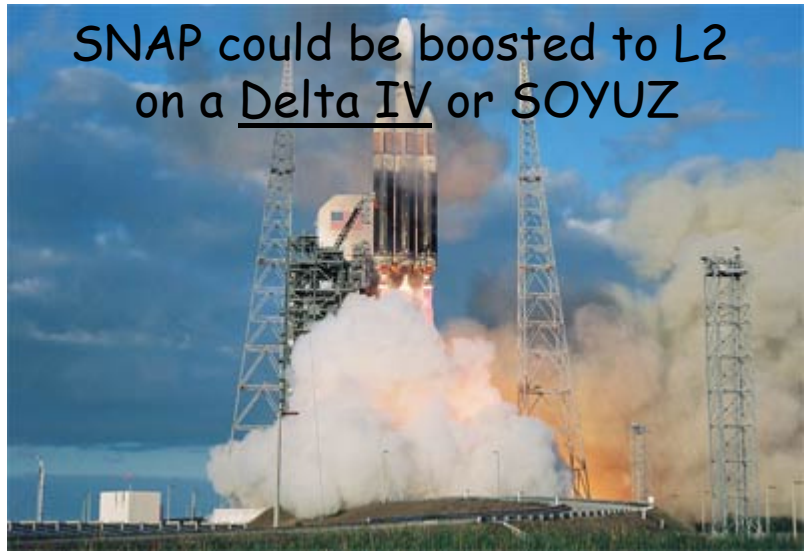
- Announcement of encouraging news on September 5, 2007

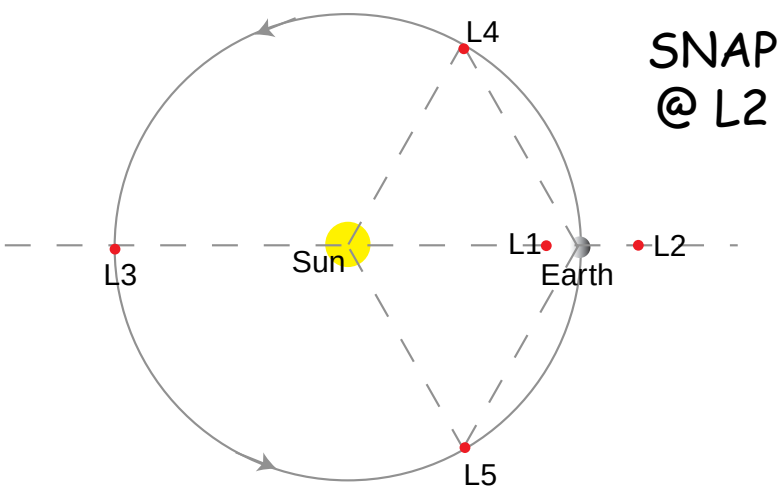
WASHINGTON -- NASA and the U.S. Department of Energy should pursue the Joint Dark Energy Mission (JDEM) as the first mission in the "Beyond Einstein" program, according to a new report from the National Research Council. Beyond Einstein is NASA's research roadmap for five proposed mission areas to study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



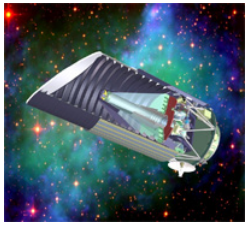
SNAP

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.





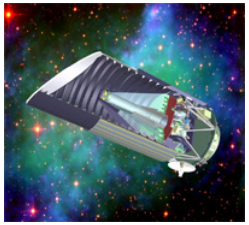
SNAP is being proposed as part of the Joint Dark Energy Mission (JDEM), a cooperative venture between NASA and the Department of Energy. If selected it will be launched before 2020.



SNAP Collaboration

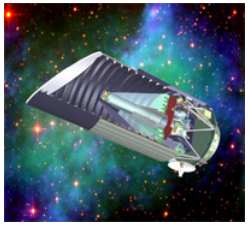
- SNAP Collaboration has ~140 scientists from

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



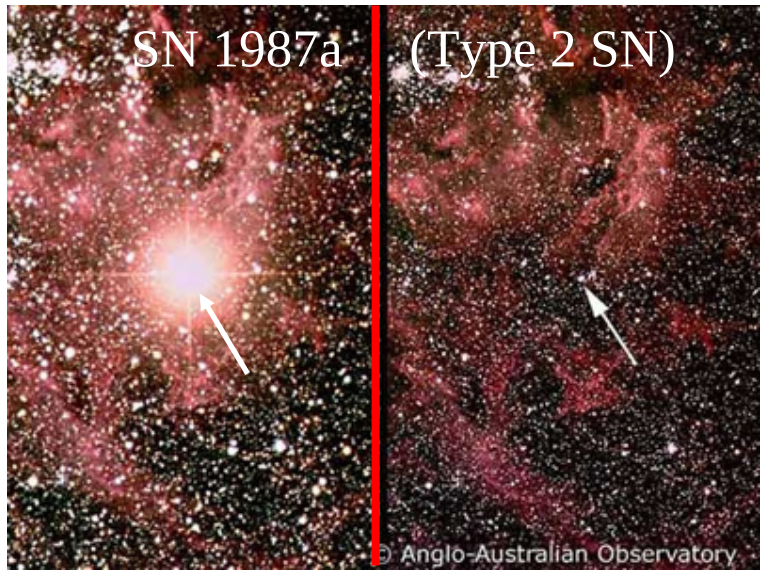
FNAL/SNAP Group

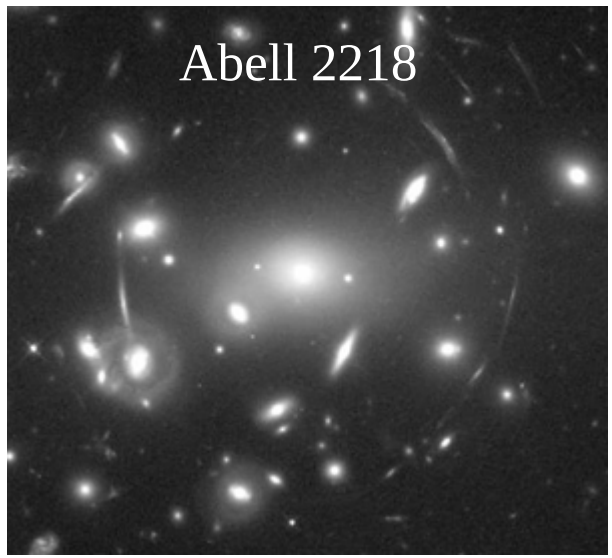
- Fermilab joined the SNAP Collaboration in 2004.
- Scientific Membership (2004-2007)
  - Allam, Annis, DeJongh, Dodelson, Diehl, Frieman, Hui, Kent, Limon, Marriner, Lin, Peoples, Scarpine, Stebbins, Stoughton, Tucker, & Wester are members of the collaboration.
  - A few have dropped off the map but are still listed in name.
  - Also, some scientists show interest and even contribute in their limited available time but aren't listed.
  - Total scientist effort over past year ~ 1.5 FTE.

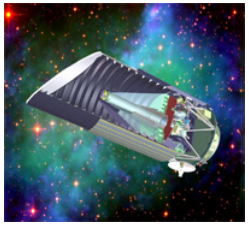


SNAP Surveys

- SuperNovae Survey
  - Repeated scans of 15 sq degrees for 36 months.
  - identify, then follow-up SN1a to z=1.7 with on-board spectograph
- Weak Lensing Survey
  - 1000 sq deg
  - Also allows study of clusters and large scale structure
  - broad scientific appeal to astronomers







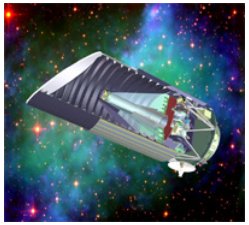
FNAL Contributions

Accomplishments, Plans, and Opportunities

Outline is photons to physics

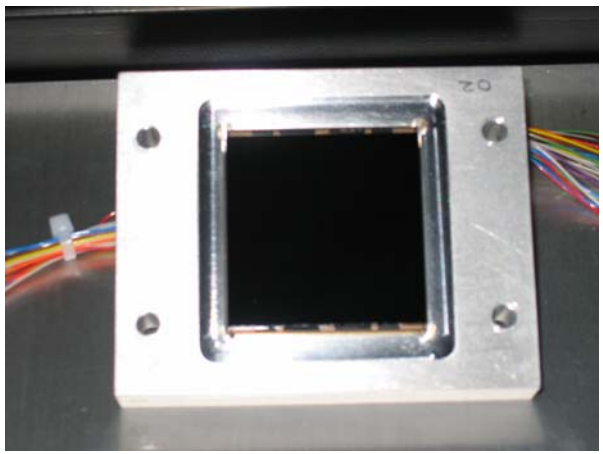
- CCDs
- Front End Electronics
- Data Management Electronics (SLICE)
- Focal plane
- Calibration
- Data Management Software
- Science

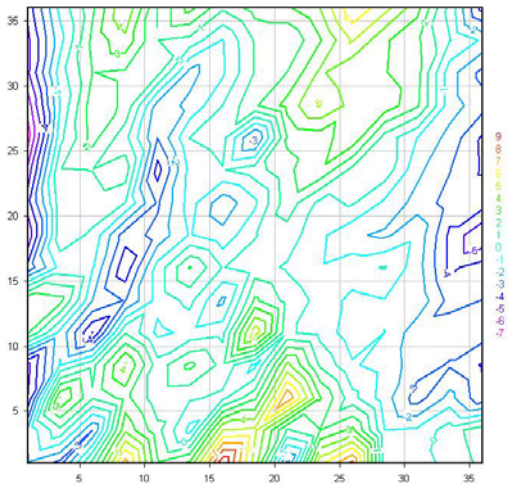
Plans are under development and the process includes internal discussions with 2nd floor and Divisions.

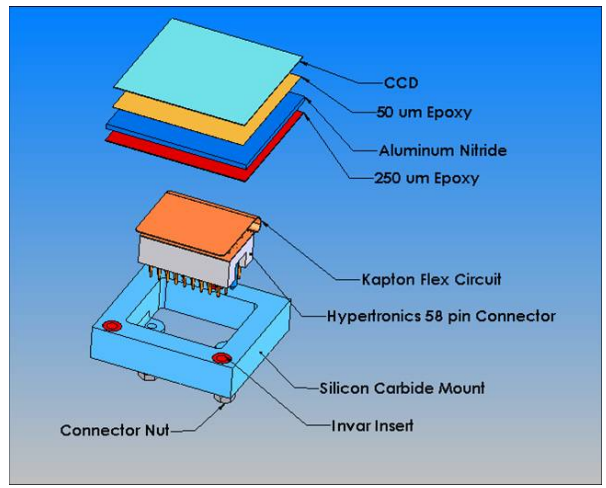


CCD Testing

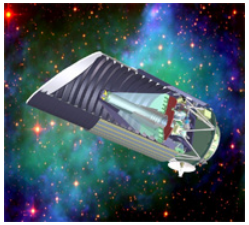
- Small tasks that are finished or near done
  - Thermo-mechanical properties of CCD packaging adhesives (FNAL TM2366-A in 2006) for FEA
  - Flatness tests of SNAP bump-bonded and wire-bonded CCDs at operating temperature 140K (topographical map).





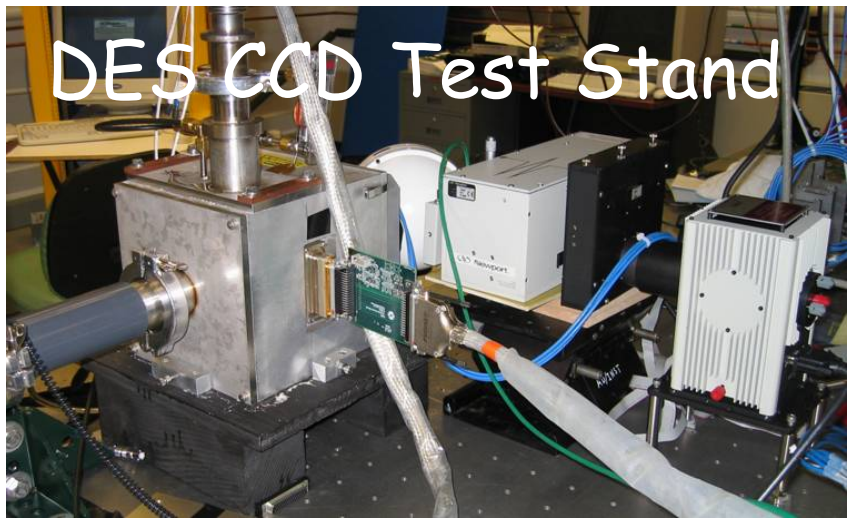


Prototype SNAP CCD at 150K
Scale is -7 to +9 μm.



CCD Production Packaging & Testing

- We have experience packaging and testing LBNL CCDs for DECam
- We plan to perform this work for SNAP
  - Startup effort began this month.
  - Production work follows similar work for DES.



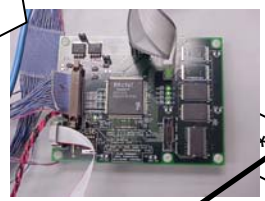
Data Acquisition Electronics Overview

80

Focal Plane Detectors + FEE

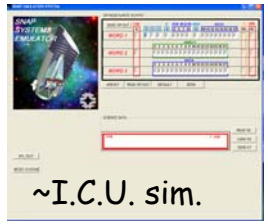
*2Gb/s

"Slice" Modules



80

ICU controls readout, allocation of mass memory, etc

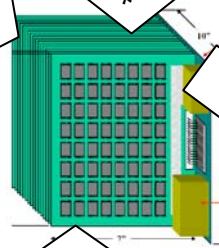


2

Data compression
Data management
Data formatting
Interface to electronics modules

*50Mb/s

*2Gb/s



Slice Crate

2

*300Mb/s

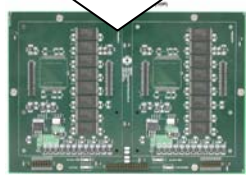
2

Telemetry

*8Gb/s

*300Mb/s

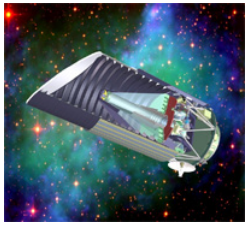
80



Memory Modules

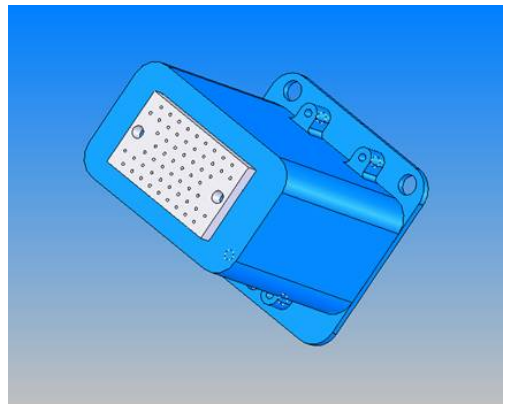
Fermilab electronic design and testing contributions since 2004

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

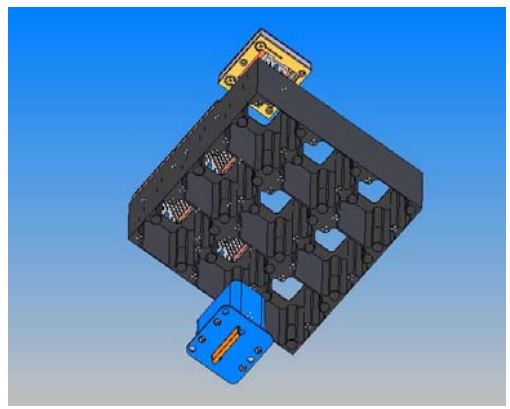


Front-end Electronics

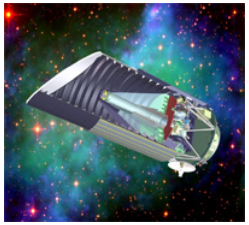
- LBNL has designed 2 ASICs to provide clocks and control and readout LBNL CCDs: CRIC and CLIC
- We might perform the production packaging
  - Design, build, and test the electronics packages that attach to the CCD.
- and testing of the CLIC and CRIC cards
  - operates at 140K



ASIC Package



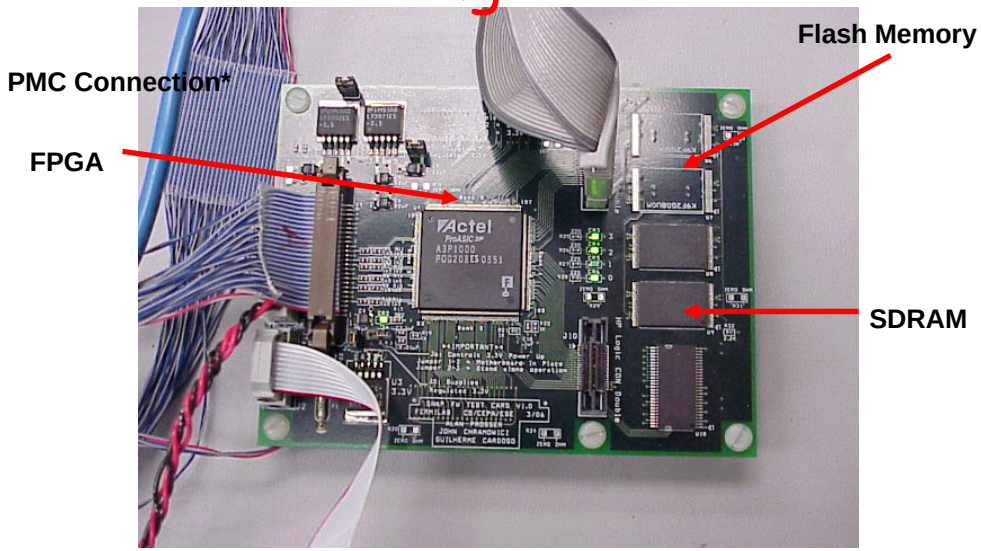
ASICs mount to CCD through Focal Plane

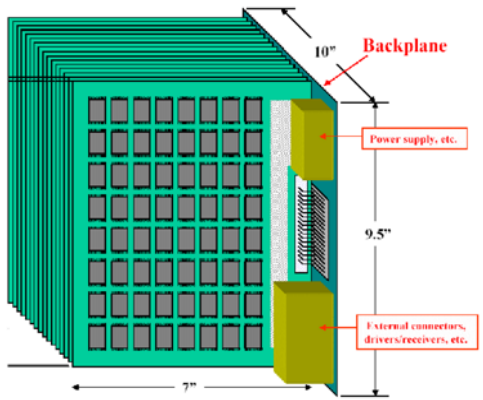


"SLICE" Status & Plans

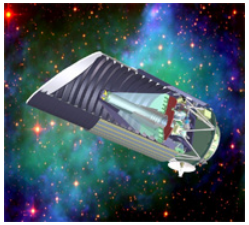
- Data management and storage
  - Built hardware breadboards with FPGAs, sdram, and flash memory
  - Writing FPGA software to perform data management and compression algorithms (~1 FTE)
  - Understand size FPGAs needed
  - Understand peak and average power per slice channel - important to the spacecraft designers.
- 2007-8 Begin development of the slice crate hardware
  - Develop and test interfaces of the "Slice electronics" with the CCD and IR readout electronics.
  - Start prototype hardware for the prototype focal plane.

Slice "daughter" card





Slice Crate



Flash Memory radiation tests

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

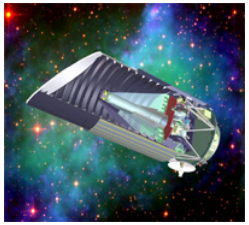
- Build, test, and read out cards using different mass memory vendors and technologies.
- Irradiate the memory using an accelerator and determine when the part fails.
  - Indiana cyclotron (200 MeV protons)
  - LBL cyclotron (heavy ions)

IEEE paper 2004

Proton Irradiation Effects on 2Gb Flash Memory

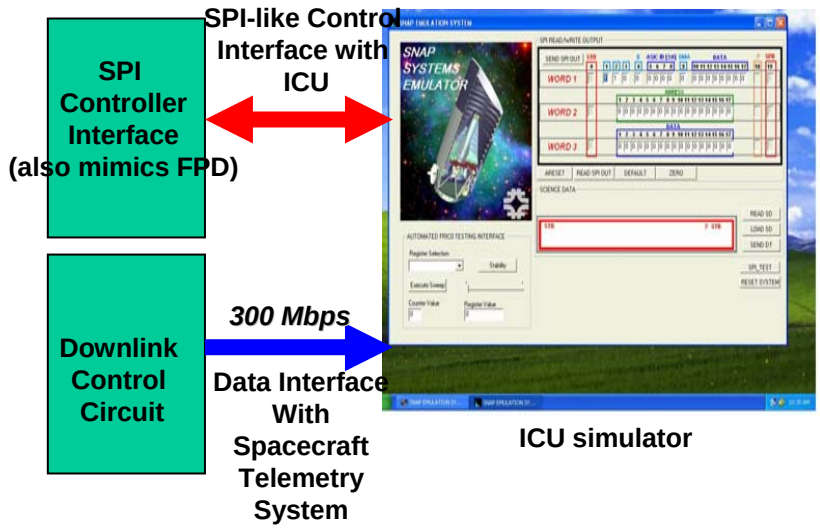
Results

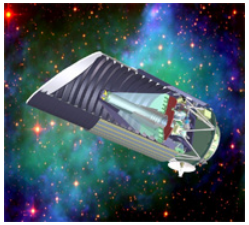
- Single Event Upsets observed
- 2 Gbyte devices (90 nm) fails at 15-25 krad
- 4-8 Gbyte devices (65 nm) fail at 25-50 krad



DAQ System Emulation

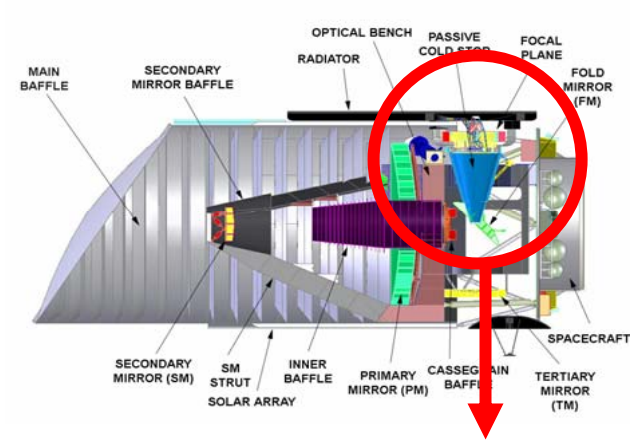
- "SNAP System Emulator" simulation of the instrument control unit interfaces (a board for the prototype focal plane that goes into slice crate)
  - Purposes:
    - Integrate Hardware Prototypes
    - Communicate with FEE (CRIC3 and Sidecar) via test boards
    - Develop more complete emulation of SPI and Downlink Controllers
    - Support slice testing with large data volumes
  - In short, simulate/prototype the entire DAQ

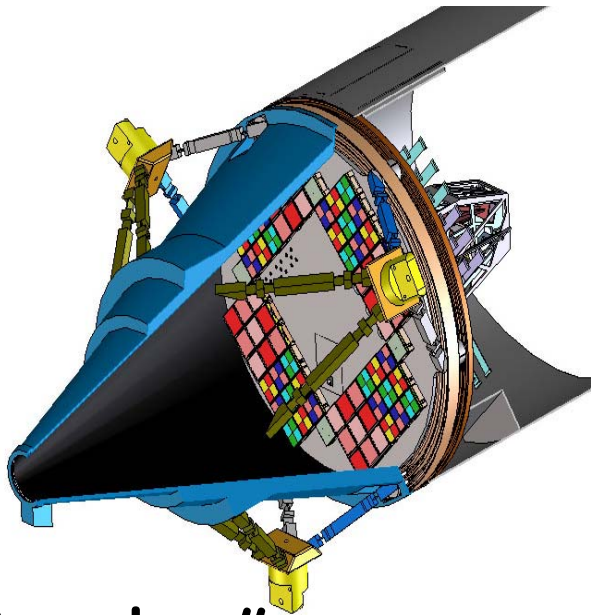




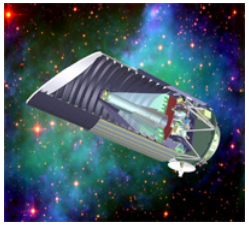
Focal Plane Assembly

- Notice that much of the Focal Plane subassembly and testing is now planned to occur at Fermilab.
- We are exploring the possibility of Focal Plane assembly and integration at SiDet.





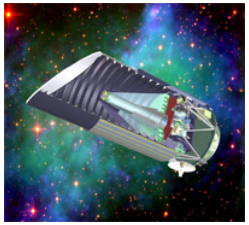
"Leadership plan"



Silicon Detector Facility

- SiDet's advantage is that it is a proven production facility
  - 6+ Cleanrooms
  - Wirebonding
  - large CMM's
  - Experienced technical staff

- Track record of successful detectors including CDF, D0, CMS vertex detectors
- & now building DECam



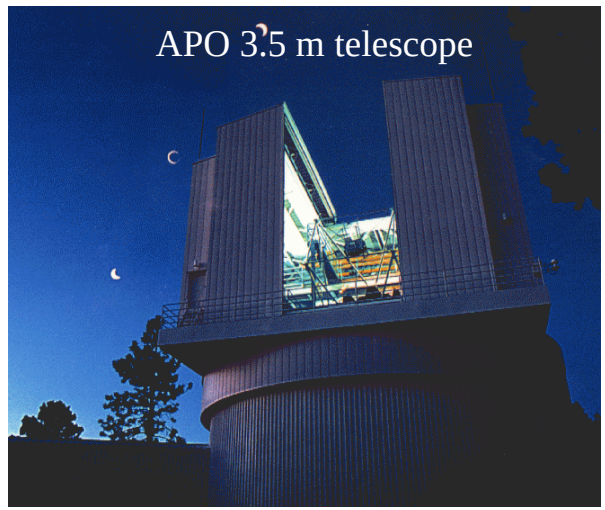
SNAP Calibration

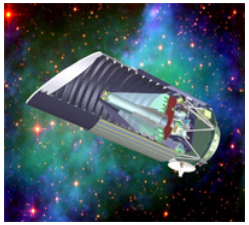
A small effort, now centered at FNAL

We want to measure the brightness of SN1a to 1-2%.

We want to be sure we measure the shapes of objects accurately.

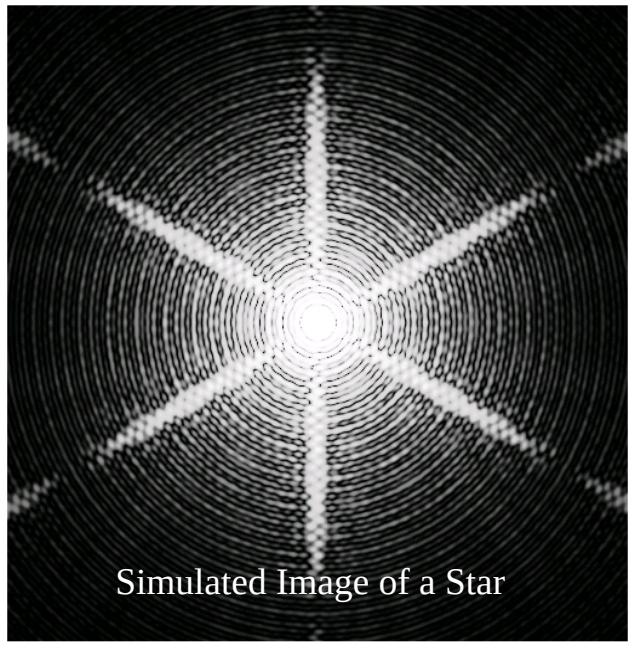
- Photometry & Astrometry
  - Standard Star Selection
    - Target selection from SDSS, then follow-up with observing runs using other telescopes.
  - Precision understanding, simulation, and monitoring of the point spread function, again with stars
- Calibration Planning
  - Calibration pipeline

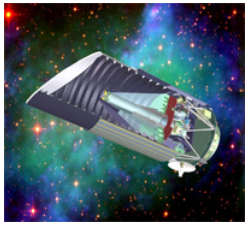




Software & Data Management

- We are performing pixel level simulations of SNAP Data
  - Leveraged with development of DES simulations
- and doing Software Management & Testing

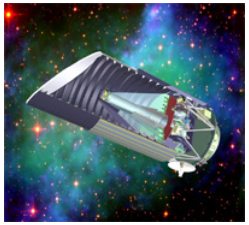




Data Management & Software

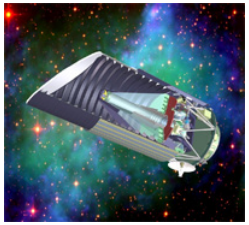
- The BEPAC report emphasized the broad scientific appeal of the wide field survey and the need for general community access to this data.
- FNAL, through it's Computing Division, has an acknowledged expertise in serving astronomical data to a broad user community as a result of the highly successful SDSS project and experience in fast processing of large HEP datasets
- We are exploring how we can best utilize these resources and expertise in support of SNAP
  - Implement and test these with simulated data
  - Design and build the data processing and analysis pipelines
  - Archive and serve the SNAP data.

"Leadership plan"



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 …

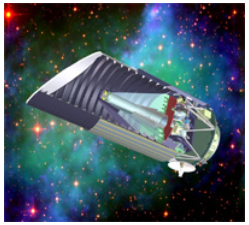


Resources (not loaded)

	FY07		FY08		Phase C/D	
	M&S	FTE	M&S	FTE	M&S/year	FTE/year
Electronics	$40k	3.5	$200k	3.5	$1000k	10
Calibration	0	0.25		1.5	0	2
Software, Simulations, Data Management	0	0.5	$150k	3	$500k	6
CCD's	$92k	0	$125k	2	$400k	6
Front-End Electronics	0	0	$25k	1	$300k	3
Science	0	0	0	0	0	2
Total One Year Costs	$132k	5	$500k	11	$2.2M	29
Total (x5 for full C/D costs)					$11M	145

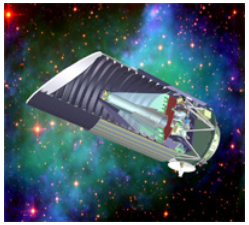
- Estimates don't include the wider-scope plans for Focal Plane Ass'y and Data Management Software.

  These plans are under development and the process includes internal discussions with 2nd floor and Divisions.



Summary

- BEPAC announcement: JDEM is 1st priority
- SNAP is the 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
- We are working with the 2nd Floor, the Divisions, and with SNAP to develop plans to increase the scope of the work in a way consistent with the strengths of Fermilab.



End of Talk

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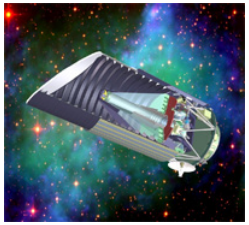
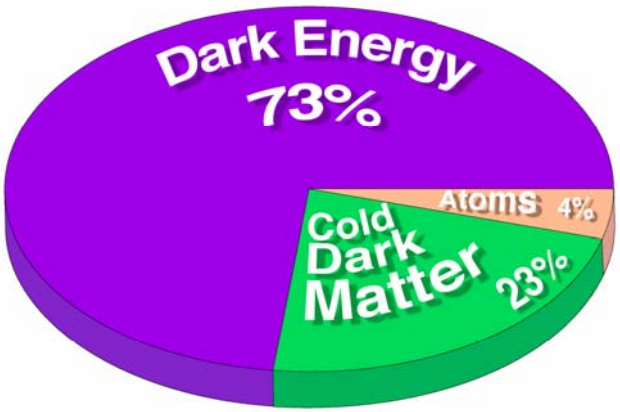
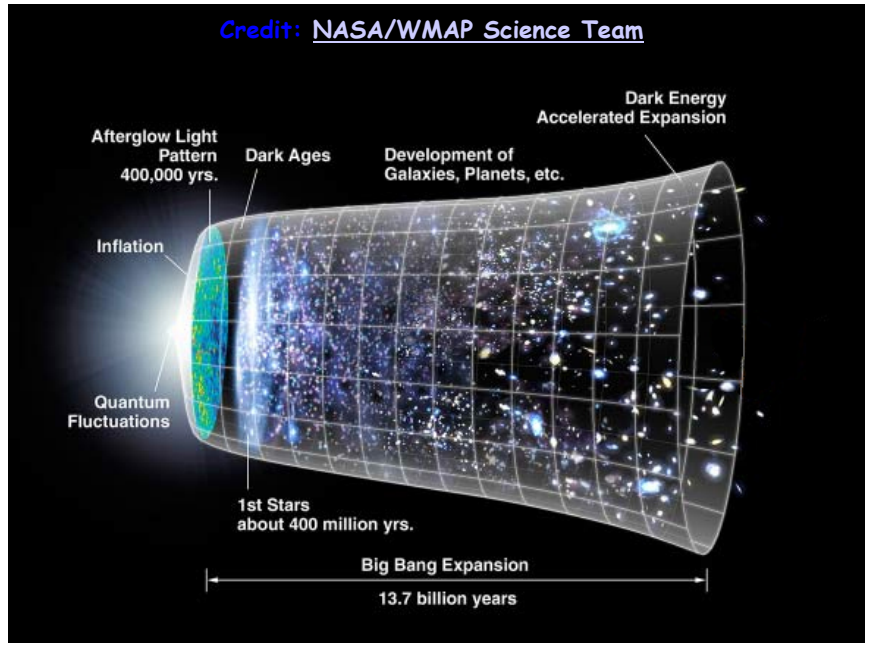


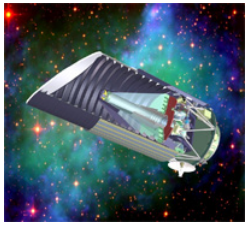
Science: Big Picture

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

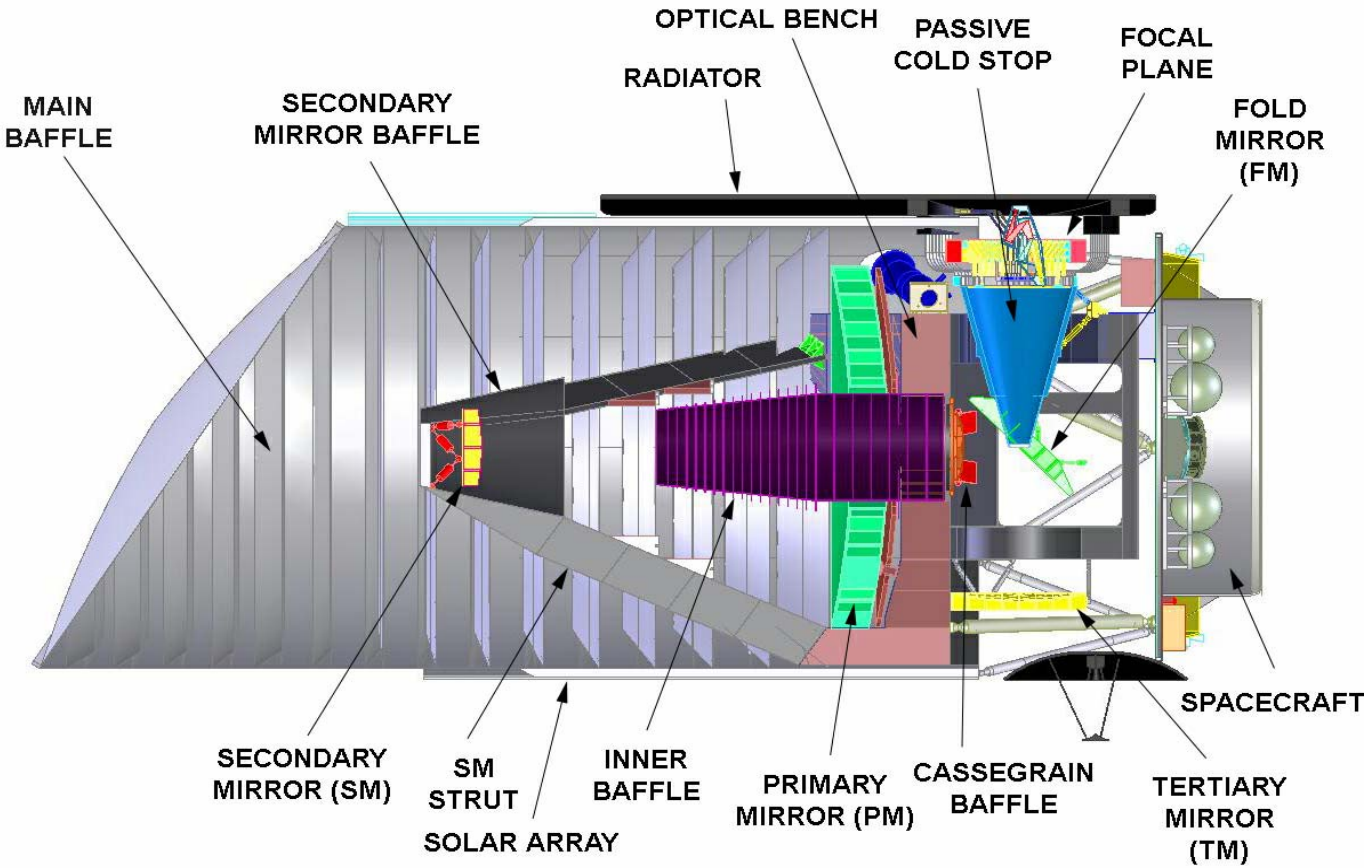




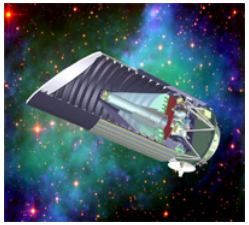
- We seek to understand the details of expansion history.



The SNAP Instrument

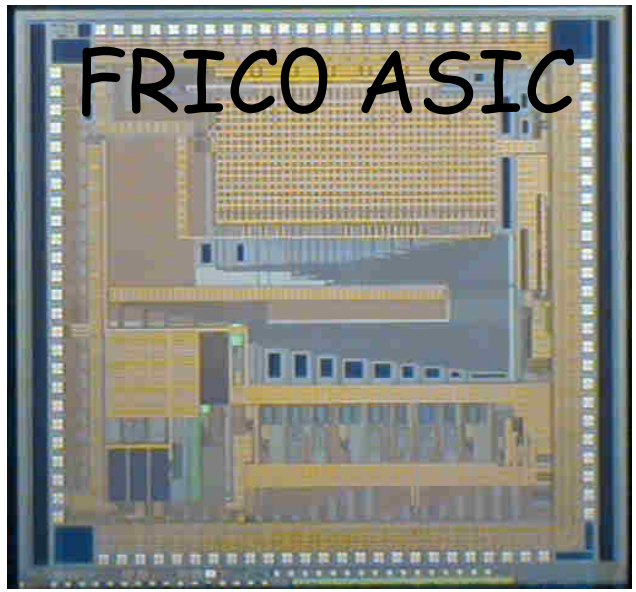


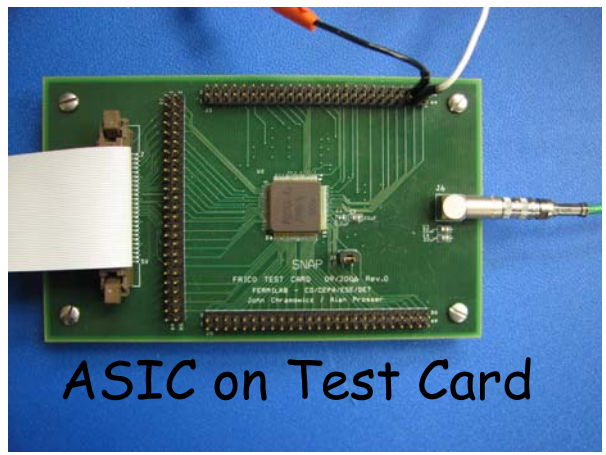
Is a telescope



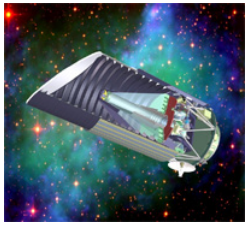
FRIC Status + Plans

- 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 FRICO 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.



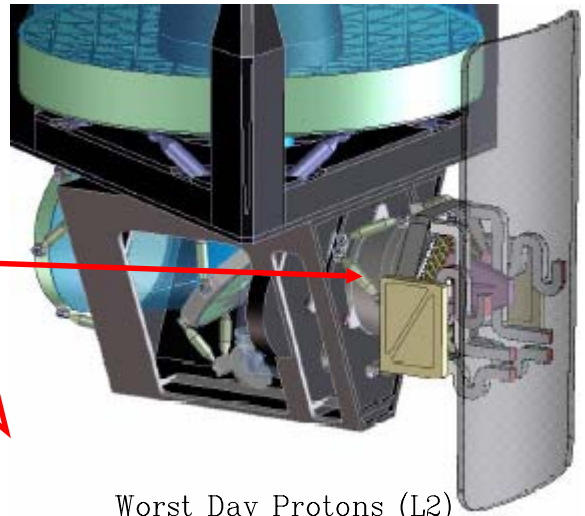


The downselect signals this is ending.



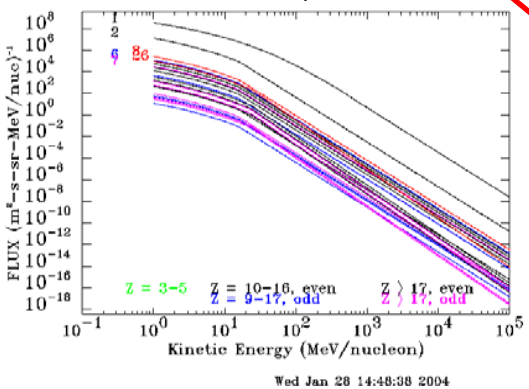
Radiation Shield MC

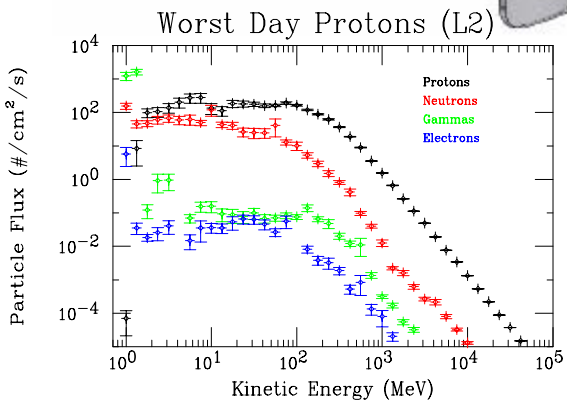
- Shield from cosmic rays, stray visible light, stray heat
- early design work



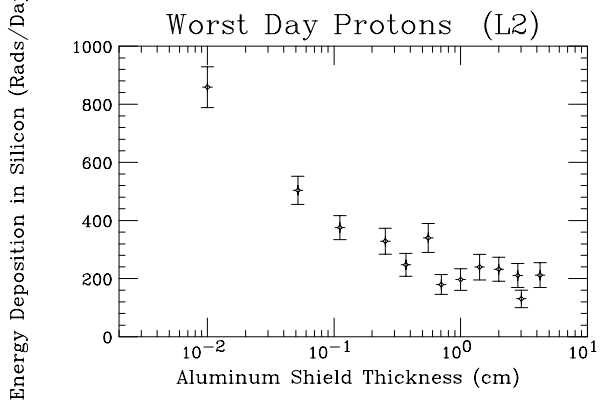
MARS Simulation of near focal plane material

"Worst Day" Protons

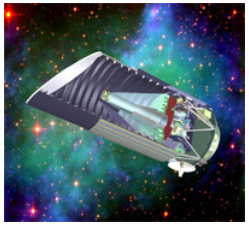




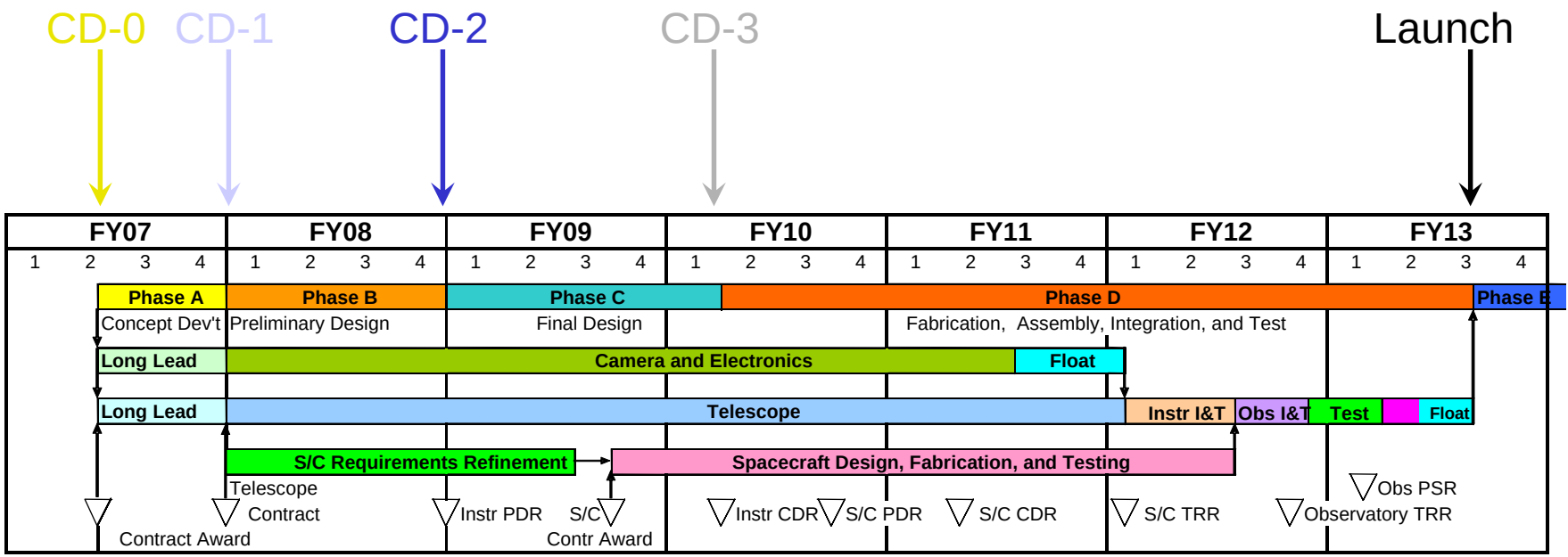
$\frac{3}{4}$ cm Al preferred



Galactic Protons result in 6.78+-0.45 Rads/Yr.
"Worst Day" Protons results in 179+-34 Rads/day for this very rare occurrence

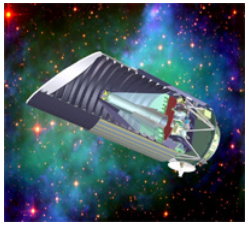


Technically Driven Schedule



	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

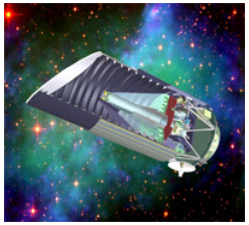
As of September 2006



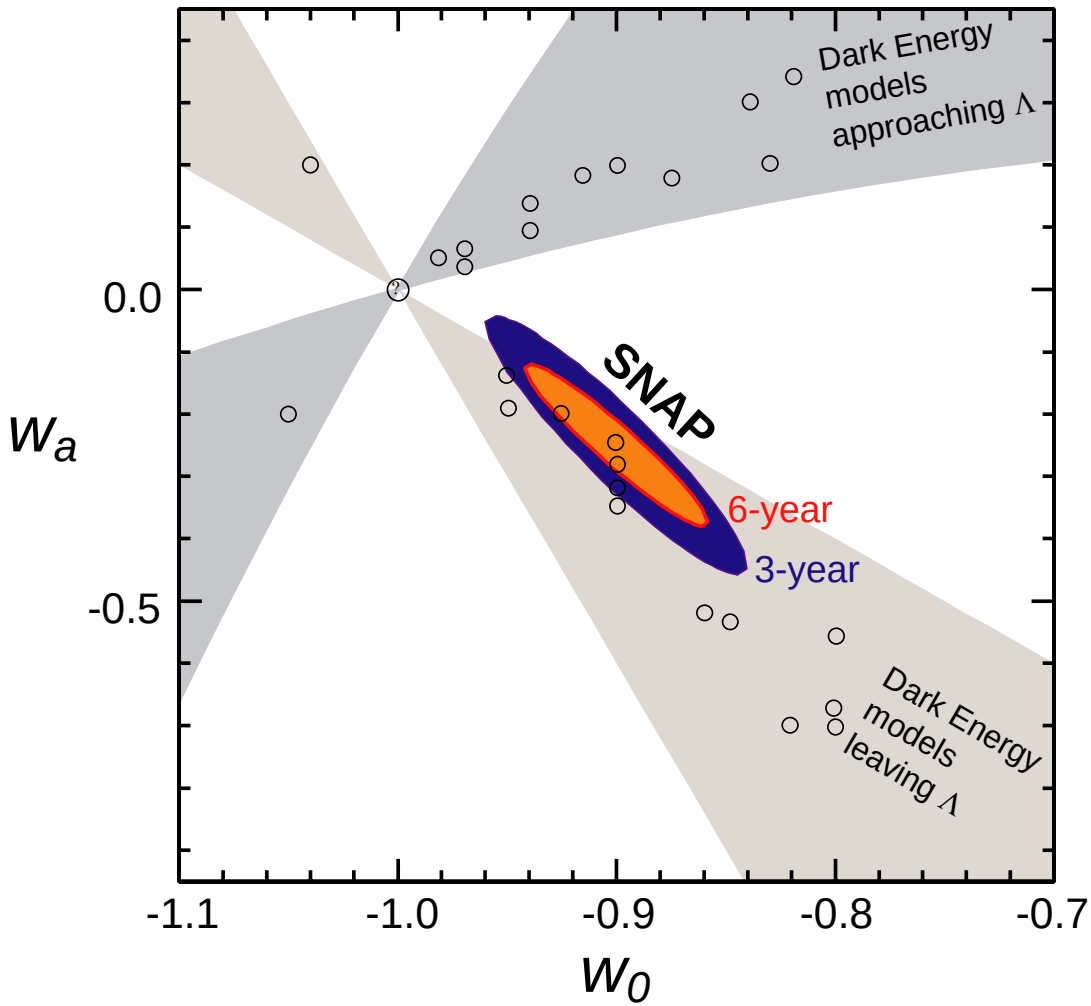
SNAP

	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(extended mission)+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
w_a
-1.1
-1.0
-0.9
-0.8
-0.7
w_0