Dark Energy searches a European perspective

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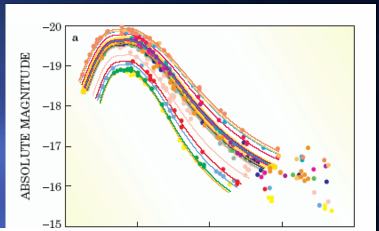
IN2P3/CNRS

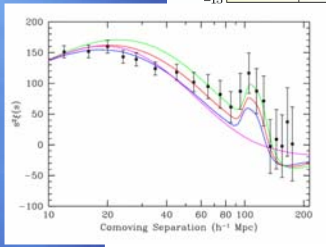
P5 meeting 20th of April 2006

Input from G. Bignami, R. Pain, G. Smadja, A. Refregier, I. Hook, D. Eisenstein, J. Frieman, P. Astier, J.Annis, A. Taylor,D. Parkinson …workshops, EDEN, Moriond, Portsmuth

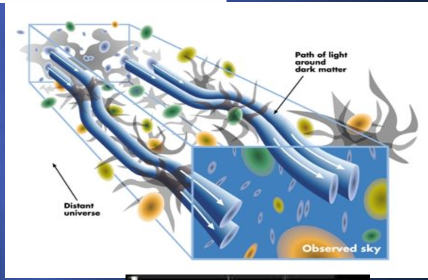
Probes of Dark Energy



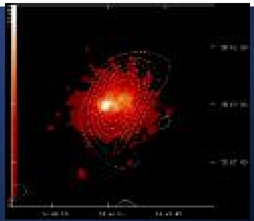
Supernovae Standard candle
Luminosity distance



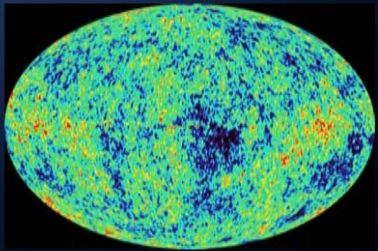
Baryon Acoustic Oscillations Standard ruler
Angular diameter distance



Cosmic Shear Evolution of dark matter perturbations
Angular diameter distance
Growth rate of structure



Cluster counts Evolution of dark matter perturbations
Angular diameter distance
Growth rate of structure



CMB Snapshot at ~400,000 yr, viewed from z=0
Angular diameter distance to z~1000
Growth rate of structure (from ISW)

Systematics of each method under heated discussion, often across cultural divides….

*Programs of European interest**

- Current programs:
  - CFHT
    - CFHT/SNLS,CFHT/CSLS
  - Nearby Supernovae
    - SNIFS
- Future ground projects
  - Baryon acoustic oscillations
    - SDSS-II, WFMOS
  - Weak lensing
    - VISTA/DarkCAM
    - DES , VST
- Space projects
  - ESA Cosmic Vision
  - DUNE
  - SNAP
- Conclusion

* Certainly not exhaustive, and certainly partial, given the little time available to prepare it

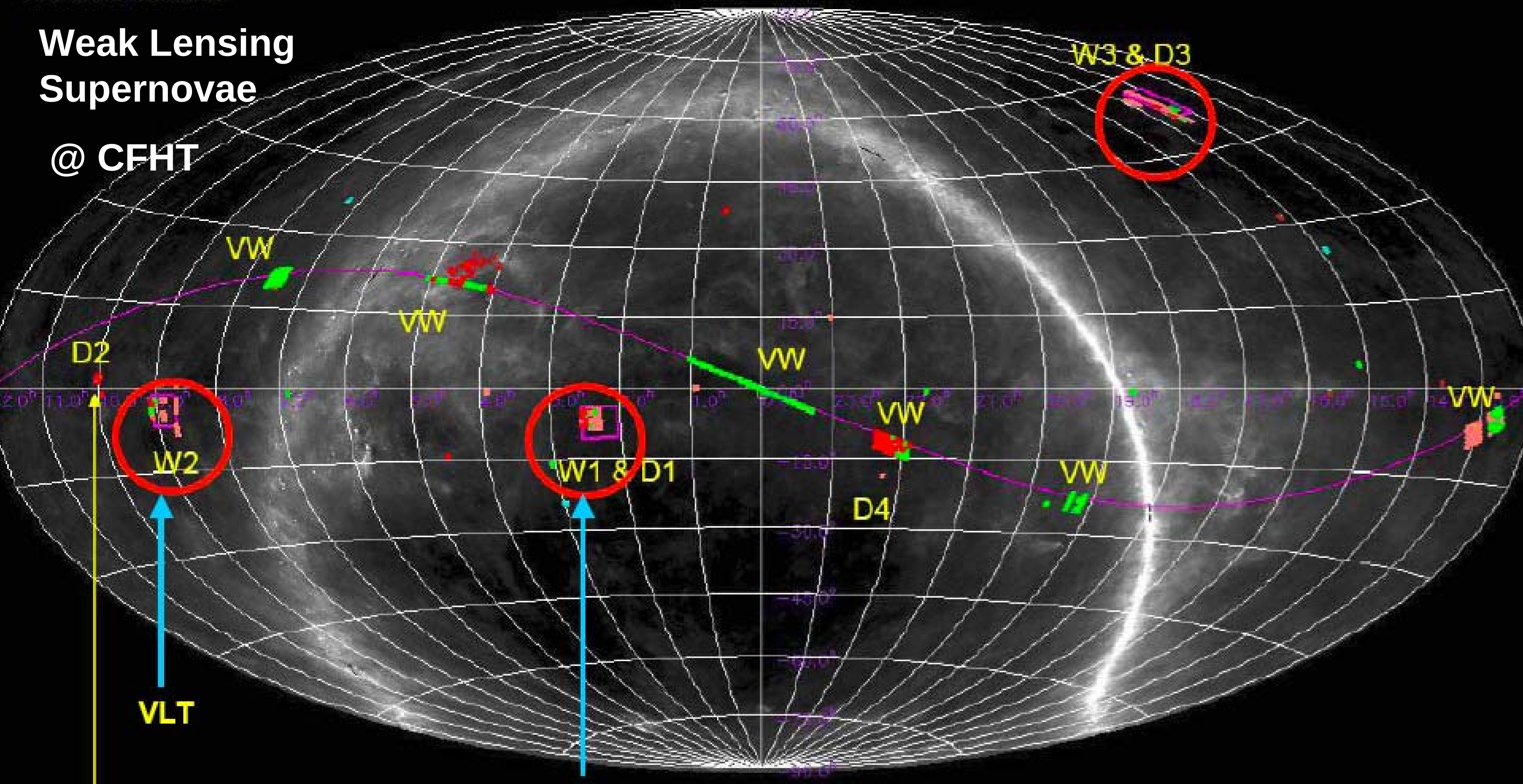
Canada-France-Hawaii Telescope Legacy Survey: Canada-France collaboration

3 fields of 50 deg^2 , 4 deep fields of 1 deg^2

Total FOV 10 times present data sets; much larger angular scale probed

Weak Lensing
Supernovae

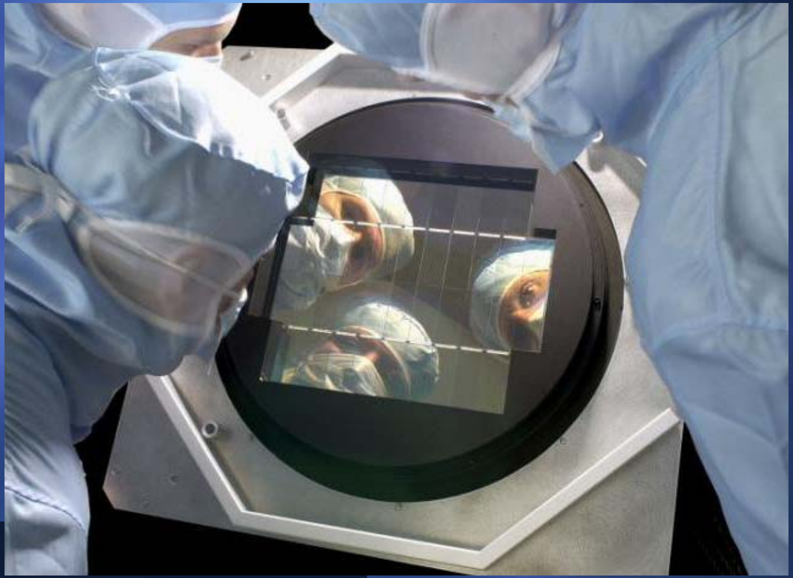
@ CFHT



pixel size: 0.186 " , median seeing: 0.8"

Terapix/Skywatcher : all data 03A-03B : 4200 Megacam images **(http://www.cfht.hawaii.edu/Science/CFHLS/)**

CFHT/SNLS

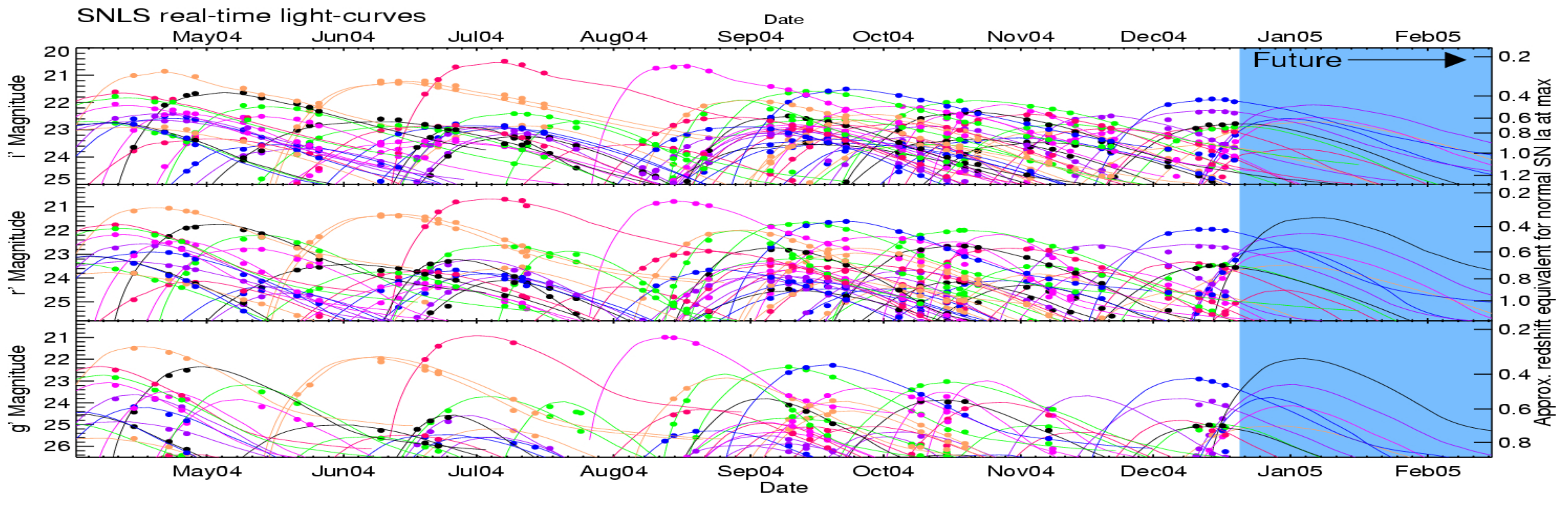


- 36 CCD imager MegaCam
  - 1 deg x 1 deg
- CFHT-LS (DEEP)
  - part of CFHTL/deep Survey
  - 40 nights/year during 5 years
  - Rolling search (every 3-4 nights for 4 fields of 1 sq deg)
  - Started August 03
- 5 epochs per field/month
  - (u),g'r'i'z'
- Top priority : 1 hr in i'
  - every 2-3 nights
  - i~24.9 AB with S/N=10

Canada, France, UK, US, Sweden, Portugal

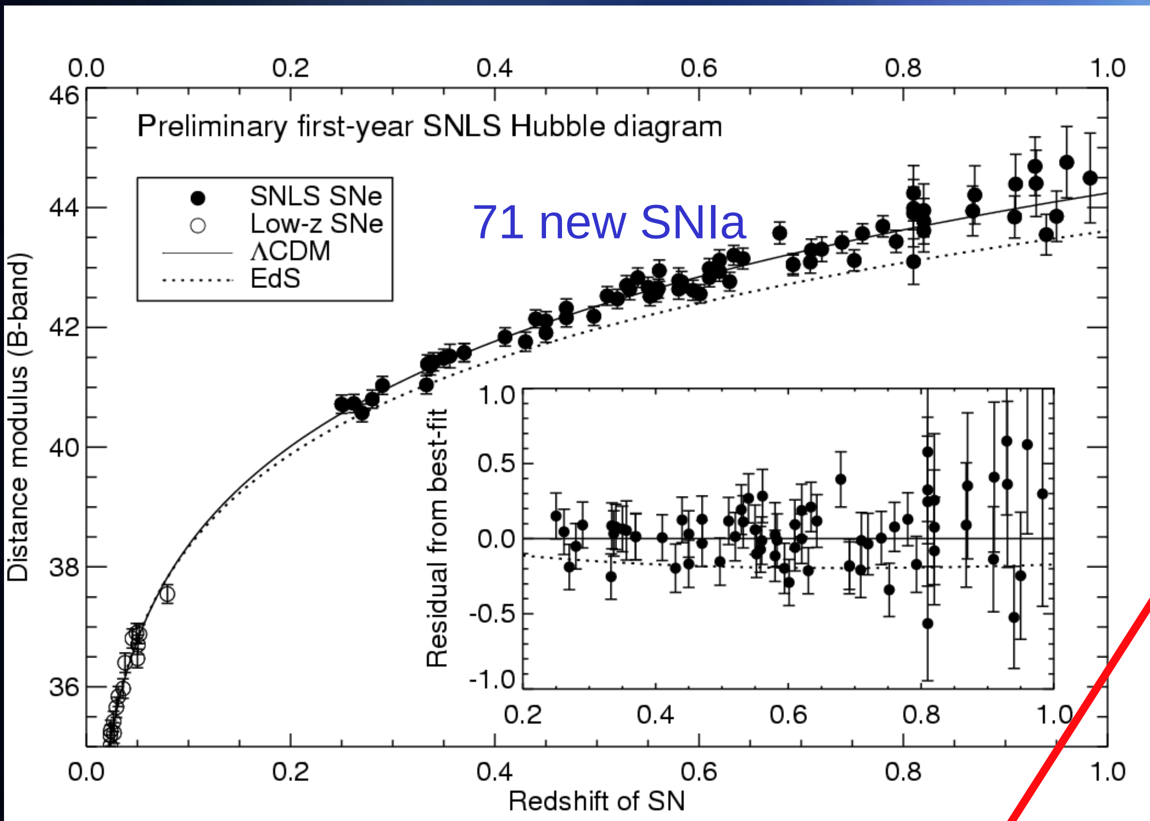
SNLS Goals

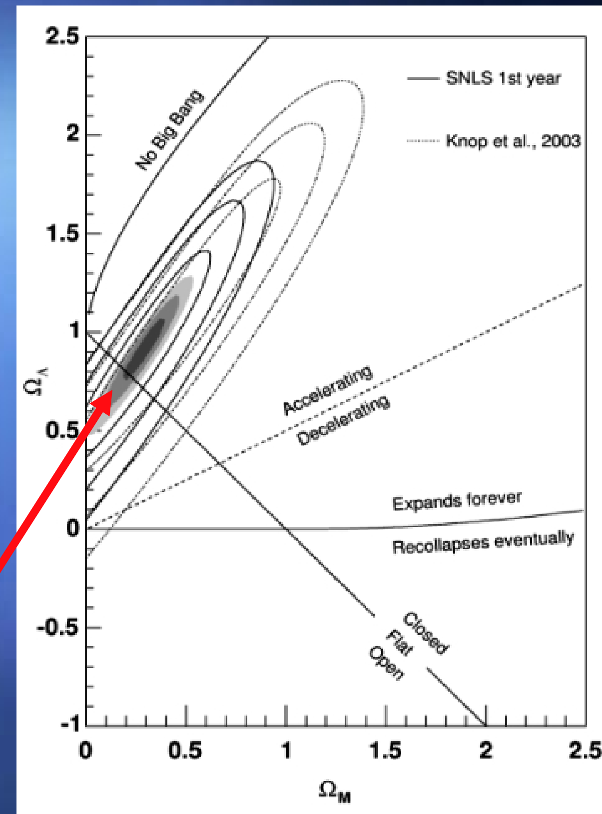
- Primary goal: Use SNe Ia to determine "w"
  - Distinguishing w=-0.8 and w=-1 at 3σ ≈700 SNeIa with 0.15<z<0.9
  - Calibration goal: 1-2% photometric accuracy
- SNLS advantages:
  - Rolling search
  - Queue observing, Multi-colour lightcurves
  - Spectroscopic follow up
- SNLS provides many consistency checks
  - SN colour evolution – multi-colour photometry check
  - Detailed studies of spectral evolution (Gemini/VLT/Keck spectra)

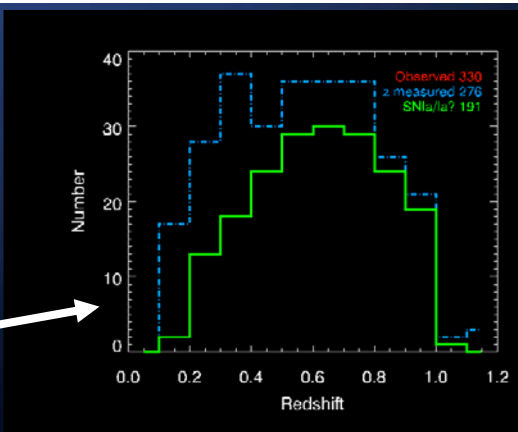


First Year Results

(Astier et al 2005)





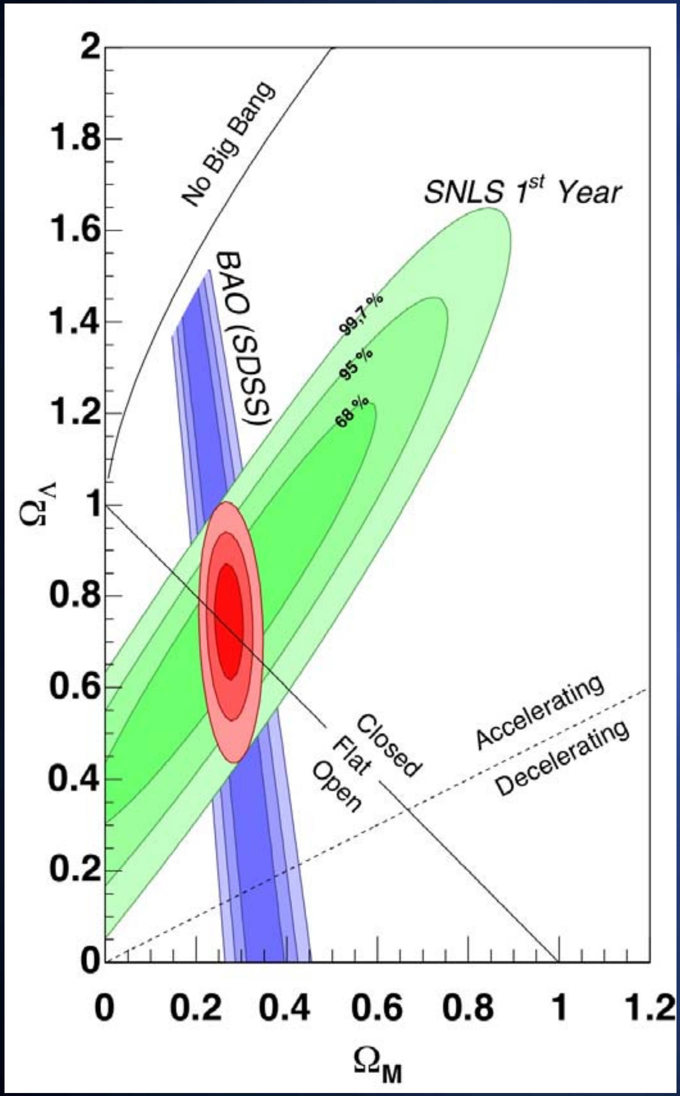


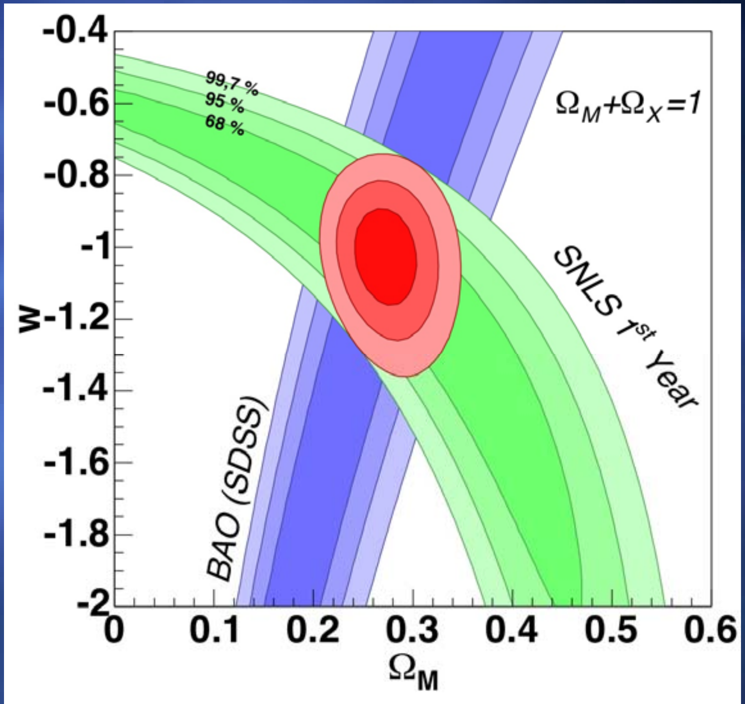
- Shaded area shows projected end-of-survey constraints

Fit of 3 parameters magnitude, stretch, color

Spectroscopy for 91 Snae 71 retained

SNLS-SDSS





Riess et al. 2004

$w = -1.02 +0.13 - 0.19$

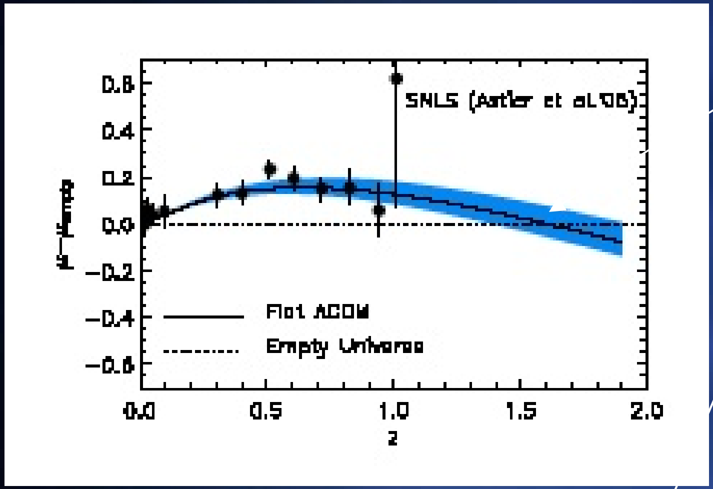
Astier et al. 2005:

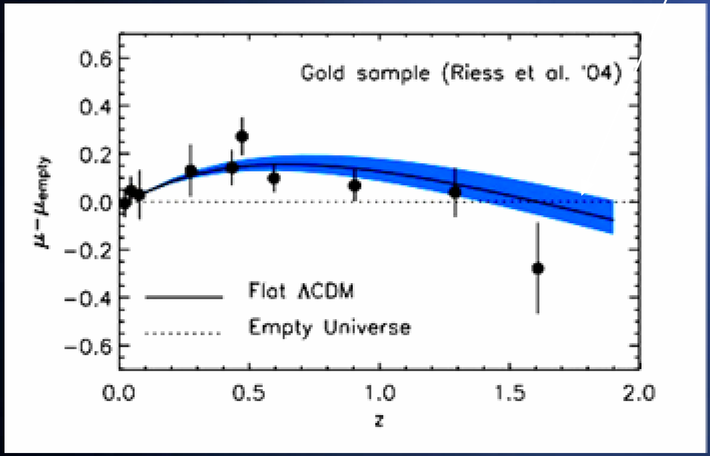
Ω_M = 0.271 +/- 0.021 (stat) +/- 0.007 (syst)

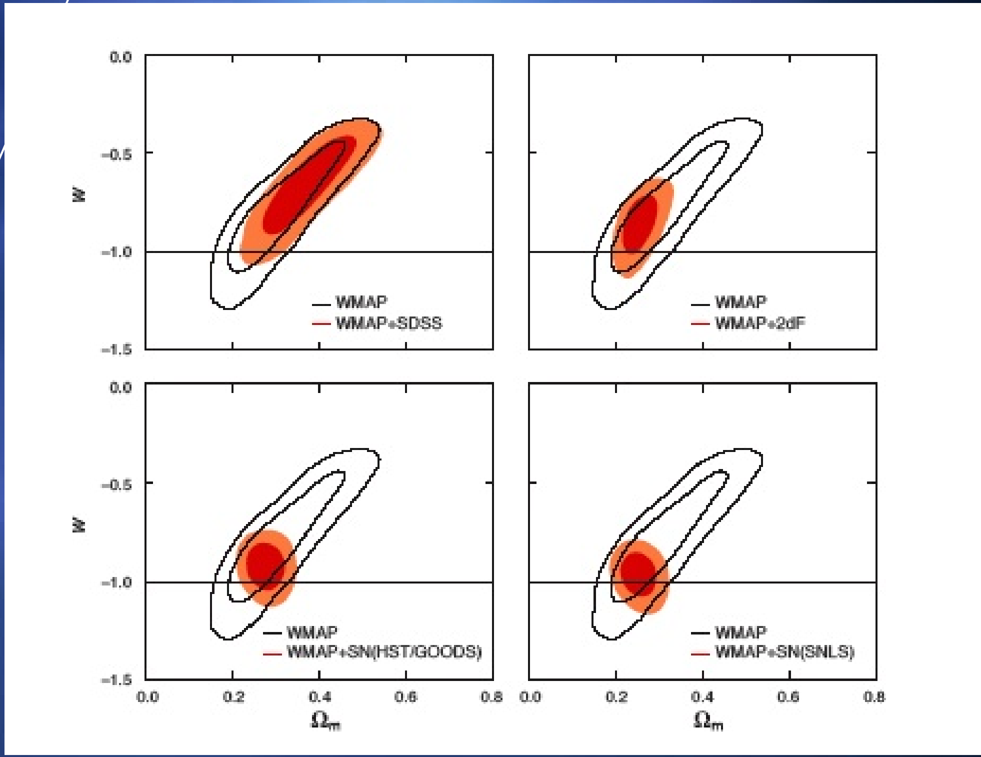
w = -1.023 +/- 0.090 (stat) +/- 0.054 (syst)

SNLS-WMAP3

WMAP prediction





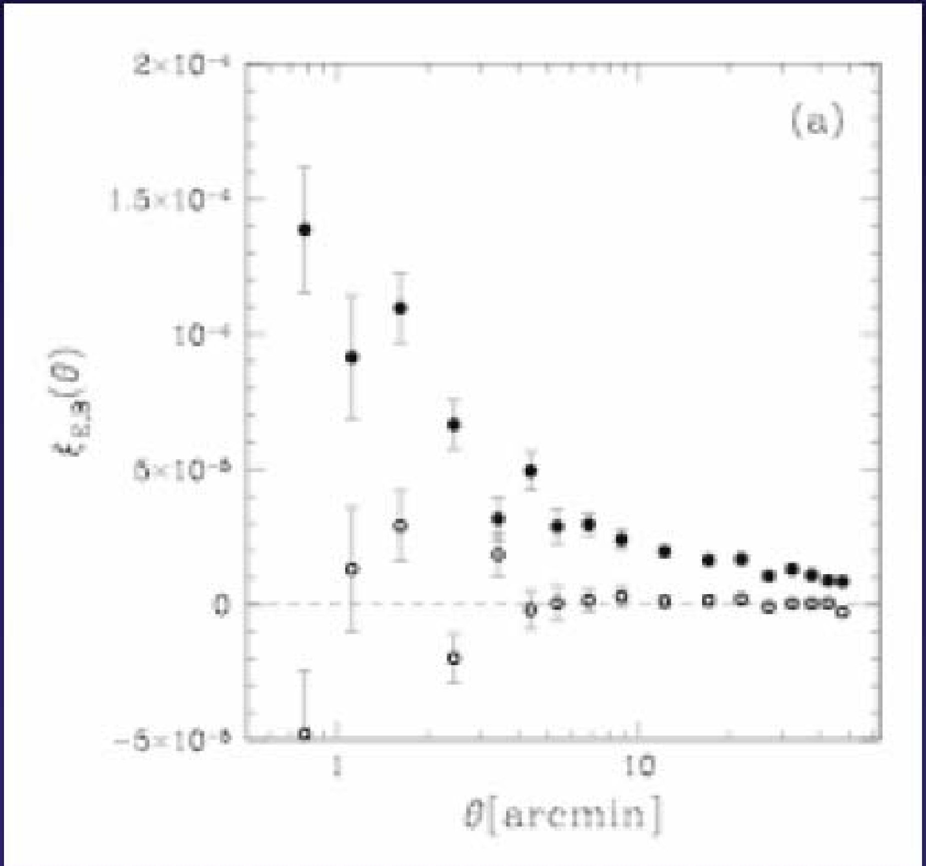


Spergel et al. 2006:

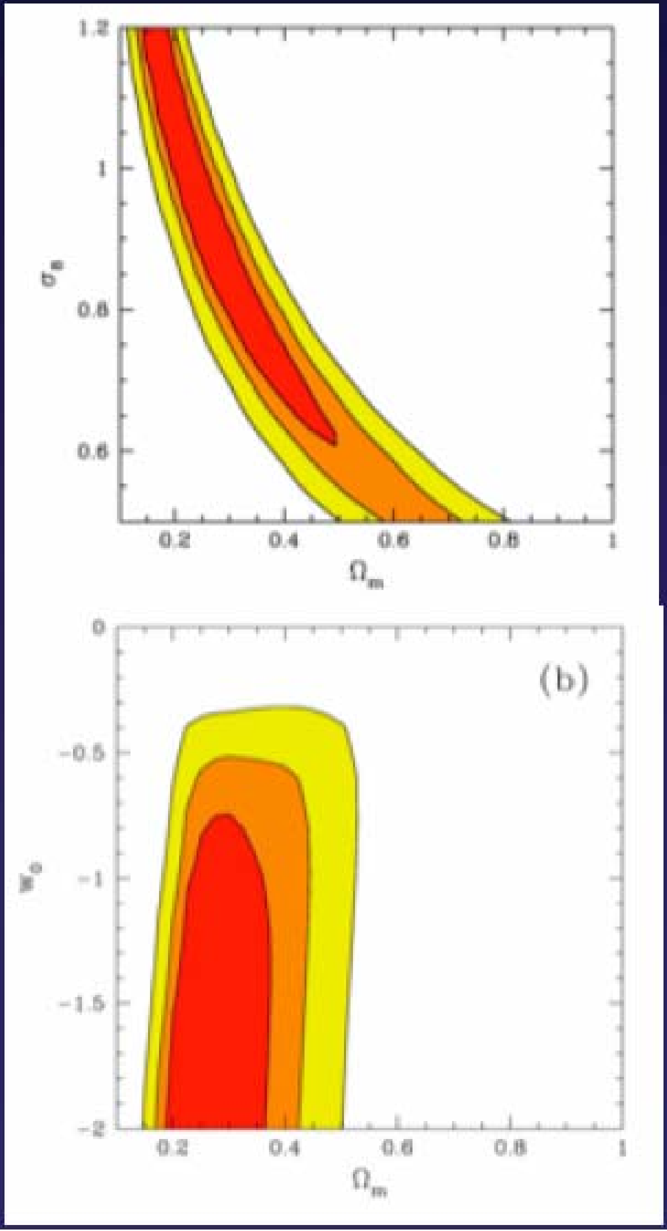
w (cte) = -0.97 +0.07 - 0.09

Ω_k=-0.015+0.020-0.016

First Results from from CFHTLS



Hoekstra et al. 2005
Semboloni et al. 2005



15%

Of

data

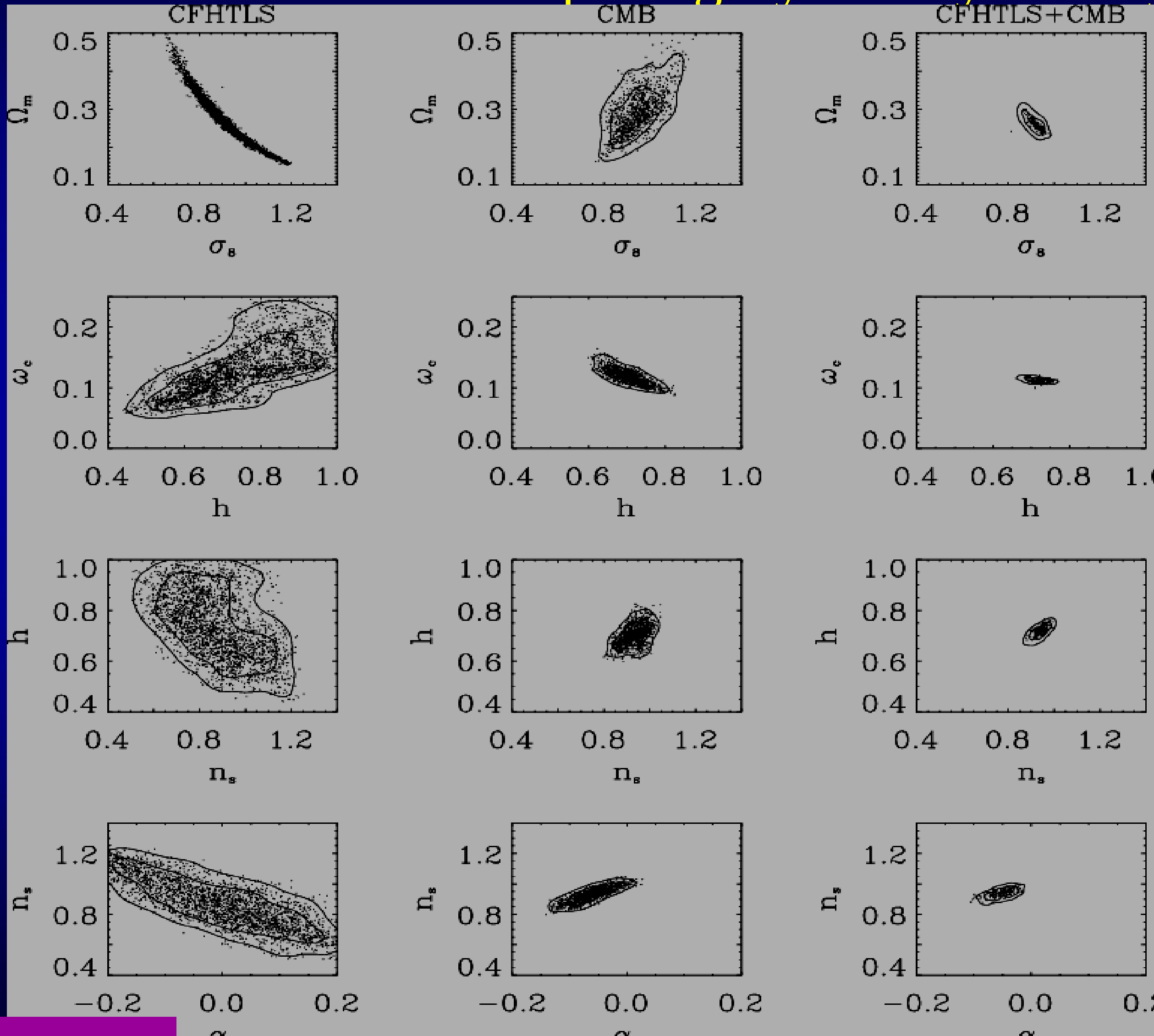
Nonlinear spectrum of Peacock &Dodds 1998

Marginalise over σ, h

Expected Results from Cosmic Shear & CMB

- Canada-France Hawaii Telescope Legacy Survey and 1-yr WMAP

170 sq deg
z=1.17



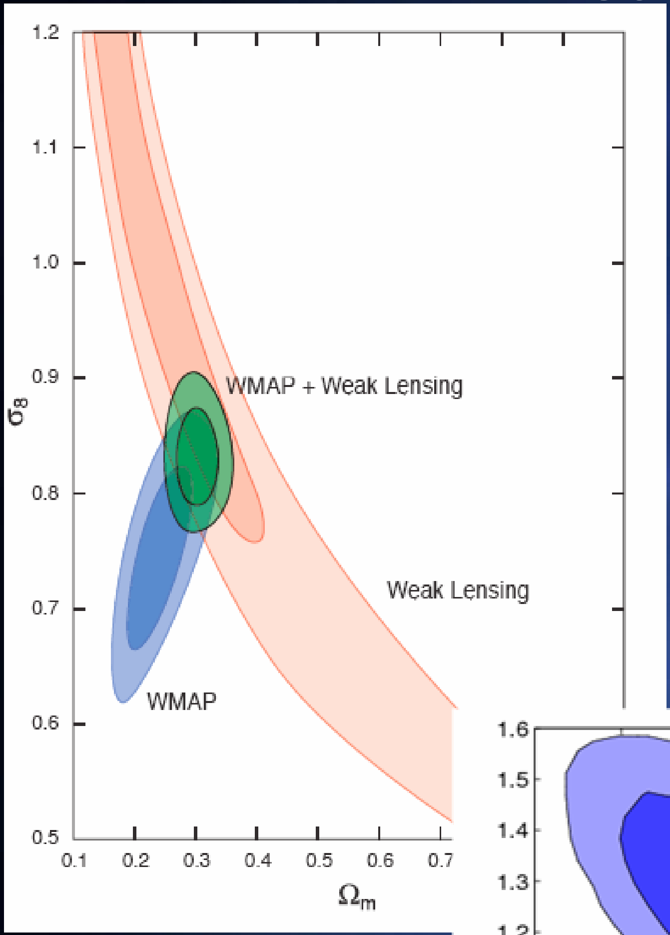
Tereno, et al 2005

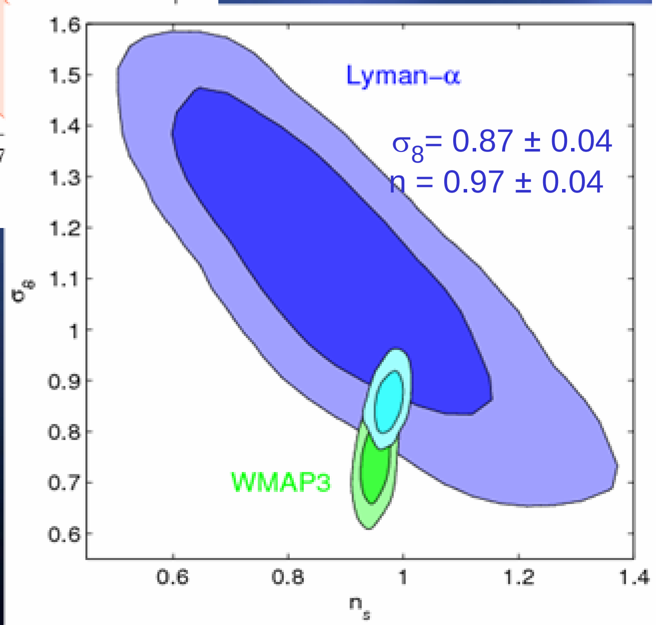
Weak lensing -WMAP3

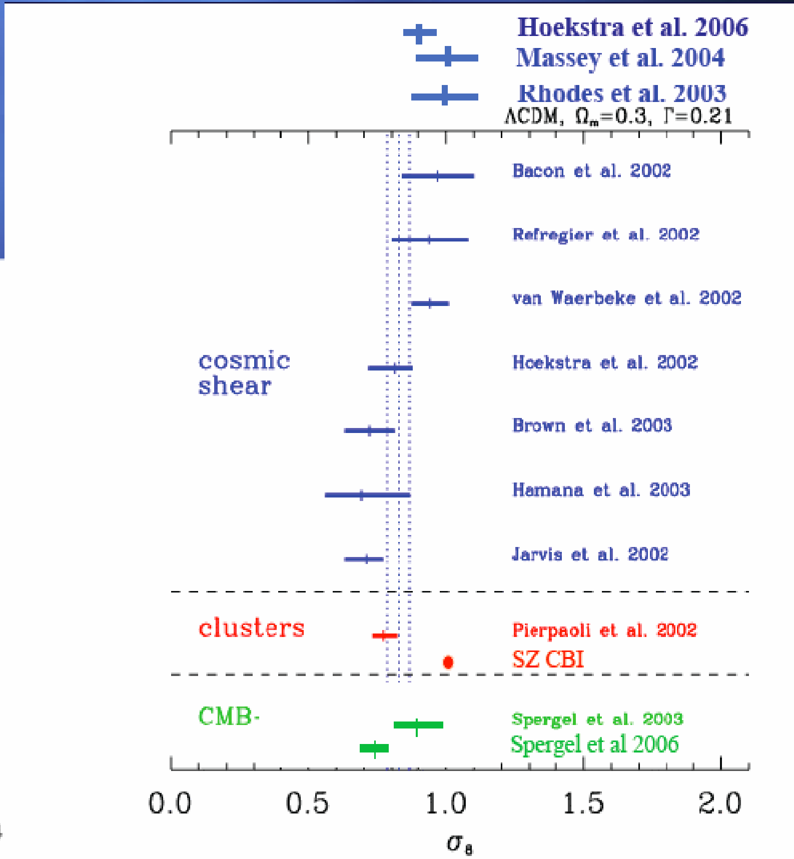
A 1,5-2 σ tension between WMAP3 and WL (also Lyman-a)

Concentrated on σ_8. Systematics*? New physics?

3D lensing ?







*Nonlinearities

Error on photo-z

SNfactory in France (SNIFS)

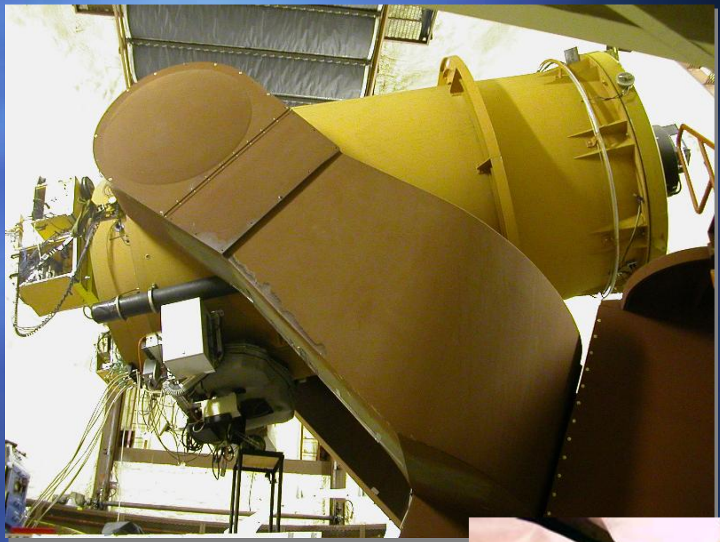
Cosmology with Ia requires :

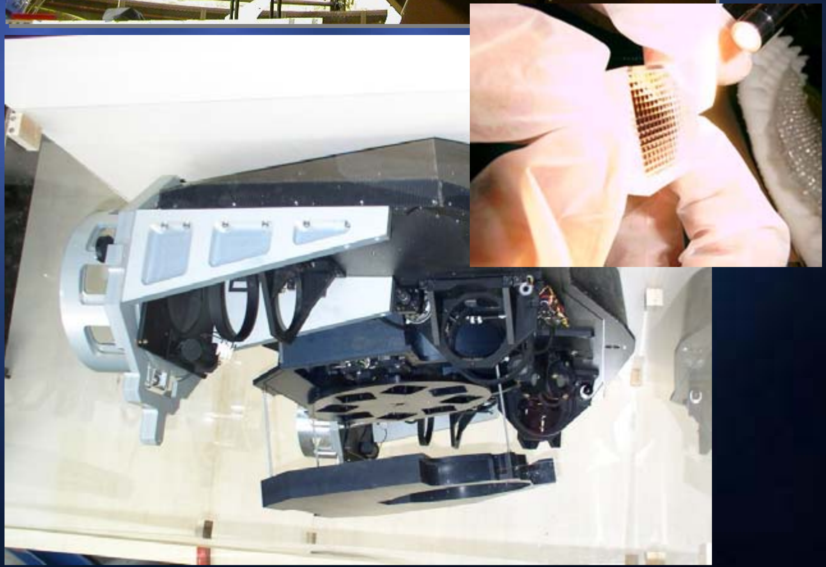
- ~ as many SNIa at low and high z (300?)
- precise control and understanding of SNIa as distance probe

$\Rightarrow$Goal of SNfactory

SNfactory :

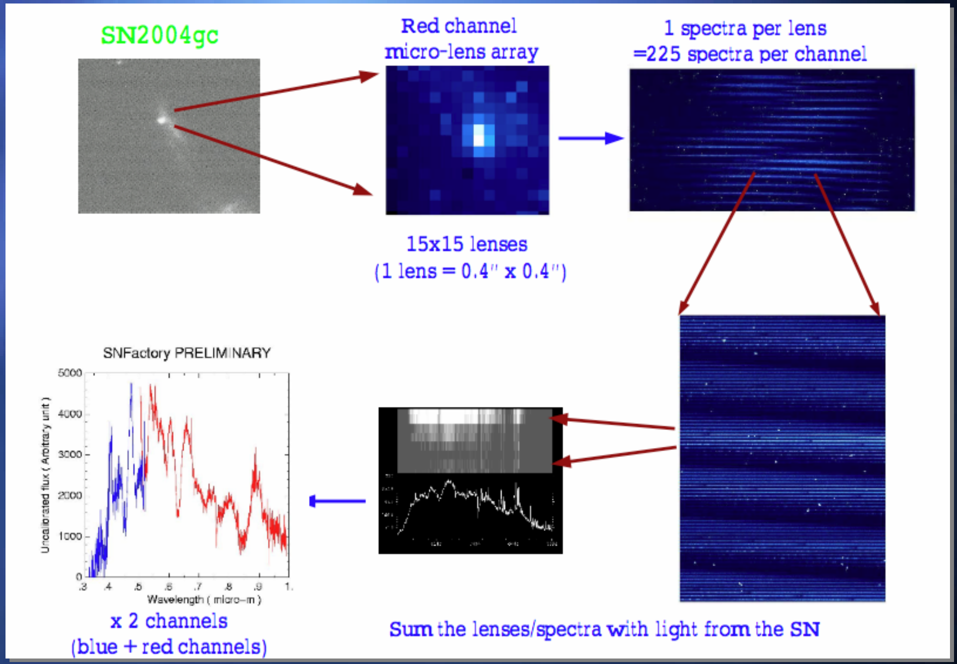
- Collaboration Franco-US
- Dedicated instrument, SNIFS, for the spectro-photometric follow-up of nearby (0.03<z<0.08) SN Ia :
  - built in France (2000-2004)
  - mounted on UH 2.2m (Hawaii) spring 2004





SNfactory : status

- 3 labs in France, 10 scientists
  3 labs in the US, 15 scientists
- Since August 2004 :
  - 200 SN observed
  - 21 “good” Ia followed
- SN Ia searches at Palomar and spectro-photometry with SNIFS still improving.
- Full acquisition power (follow up of ~2 new Ia / week) should be reached before end of summer 2006

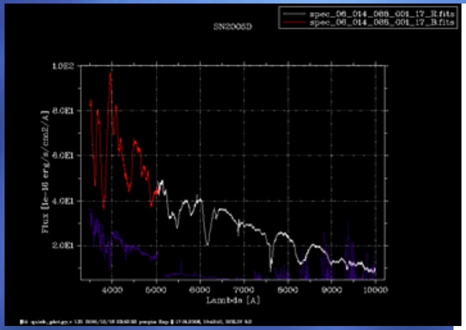


Spectro-photometry with SNIFS

Low z Sne Ia: plan

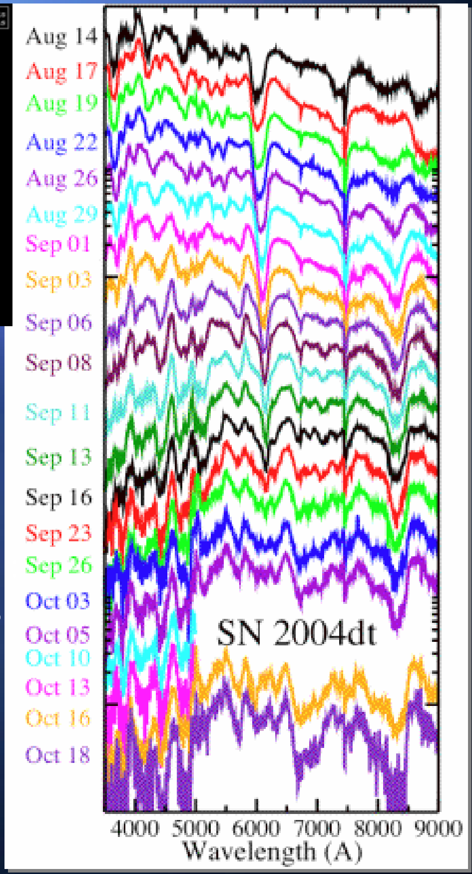
- Today high z programs, like SNLS, are limited by low z data statistics.
- Questions on SNIa systematic at the core of the future programs from space/ground.
- A laboratory of new methods to predict absolute luminosty

Support and development of SNfactory program mandatory in the “big picture” plan.



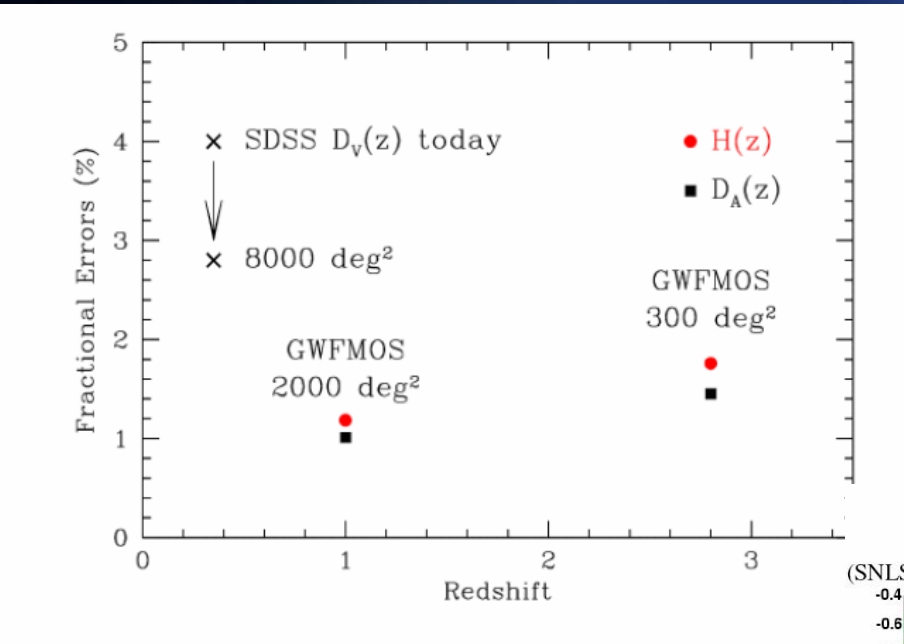
SN2006D : clear track of C in early spectra

SNfactory like observations mandatory for using Ia as “probe for cosmology”



SN2004dt: followed for more than 60 days.

BAO+Snae: dark energy constraints by 2009?

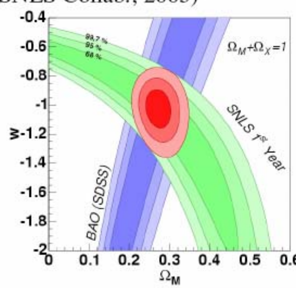


To be optimised using
Integrated Parameter
Survey Optimisation
IPSO Bassett 2004

SNLS+BAO (already SDSS-II) sufficient to measure w at 5%

SNe+BAO:Short term forecasts for w

(SNLS Collab., 2005)

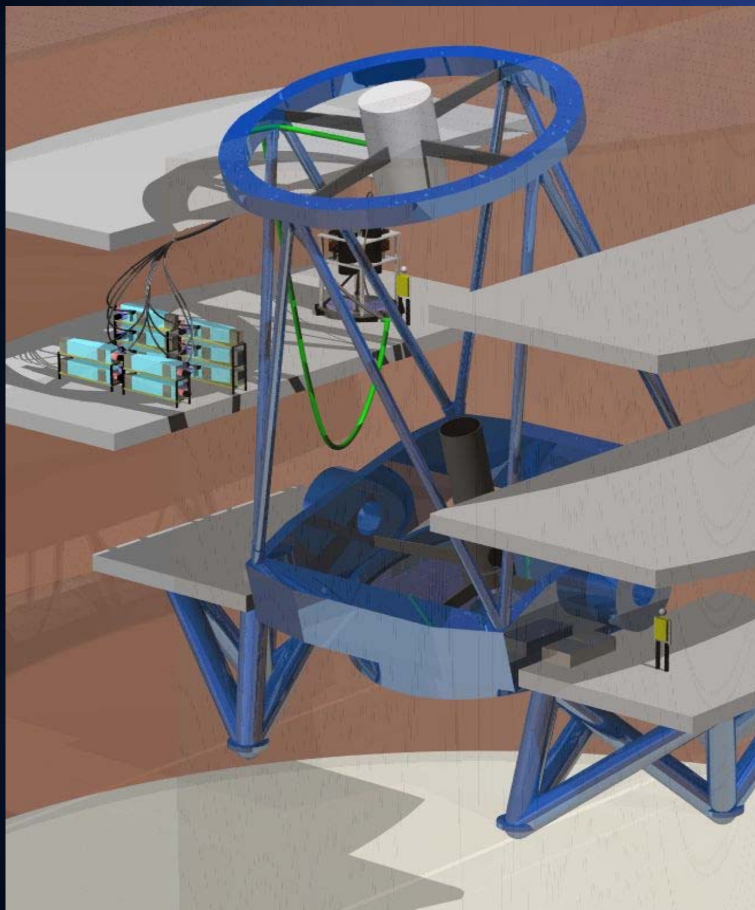


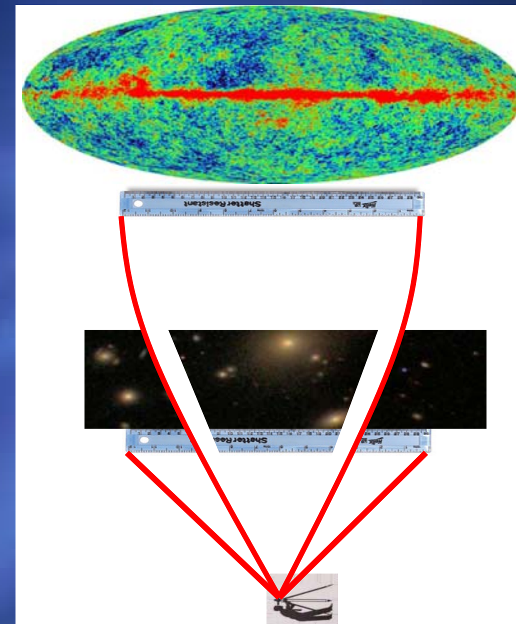
Expected "realistic" statistical improvements of the (Ω_M, w) constraints (flat universe).

SNfactory
SDSS SNe
SNLS SNe

	Nearby SNe / Distant SNe	44 / 71	inf. / 71	44 / 213	132 / 213	132 / 500	250 / 500
with current BAO accuracy	$\sigma(\Omega_M)$	0.023	0.019	0.019	0.019	0.018	0.018
	$\sigma(w_0)$	0.088	0.073	0.076	0.064	0.060	0.055
BAO x 2 (4000->8000 deg^2)	$\sigma(\Omega_M)$	0.016	0.014	0.014	0.013	0.013	0.013
	$\sigma(w_0)$	0.081	0.062	0.067	0.054	0.049	0.044

Baryon Acoustic Oscillations for dark energy WFMOS





- Anglo-Australian Observatory
- John Hopkins University
- University of Durham
- University of Portsmouth
- Canadian Astronomy Data center
- National Optical Astronomy Observatory
- University of Oxford

Target Specifications for WFMOS

- Wide-Field
  - 1.5° aperture diameter
  - Wavelength range: 0.39–1.0 µm
- Fiber-Fed Optical
  - "Echidna"-style fiber-optic focal plane
  - Spatial sampling: ~1 arcsec fiber entrance
- Multi-Object
  - ~4500 simultaneous observations
  - Over 20,000 astronomical spectra per night
- Spectrograph
  - Moderate to high resolution (R=1000-40,000)

- Originally intended for Gemini, the advantages of building WFMOS for Subaru, sharing Gemini & Subaru resources, has since been recognized.
- The WFMOS feasibility study has lead to a RfP for two competing concept studies, for review Oct/Nov 2006.

WFMOS Science

- WFMOS has two flagship science programs:
  - Acoustic oscillations ⇒ What is the dark energy?
  - Galactic archeology ⇒ How do galaxies form?

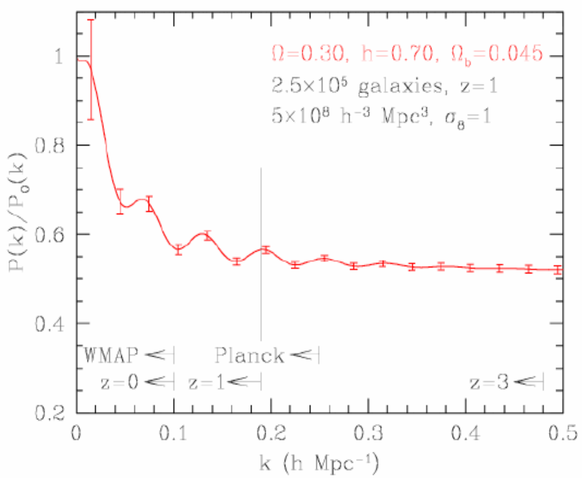
- WFMOS can also perform , among others:
  - Studies of large-scale structure
  - Formation and evolution of galaxies at high redshift
  - The growth of structure..
  - Dark matter distributions via kinematics of LG galaxies

- Additional science from survey data…
  - **Constrain dark energy from cluster counts and Alcock-Paczsynki test**
  - **Spectroscopically identify thousands of SNe Ia**
  - Test reciprocity relation $d_A/d_L = (1+z)^2$ to constrain GR and photon conservation (axion-photon interactions)
  - Measure luminosity functions & star-formation rate densities with redshift & environment
  - Constrain shape of primordial power spectrum to 2% (mass of the neutrino to 0.1eV (2σ)

WFMOS BAO

Survey	R_{lim} (AB mag)	Target Surface Density (deg^{-2})	Total Area (deg^2)	Total Sample Size (# objects)	Total Survey Time[1] (hrs/nights)
Dark Energy $z = 0.5 – 1.3$	22.7	1000	2000	2×10^6	1530/153
Dark Energy $z = 2.3 – 3.3$	24.5	2000	300	6×10^5	1360/136

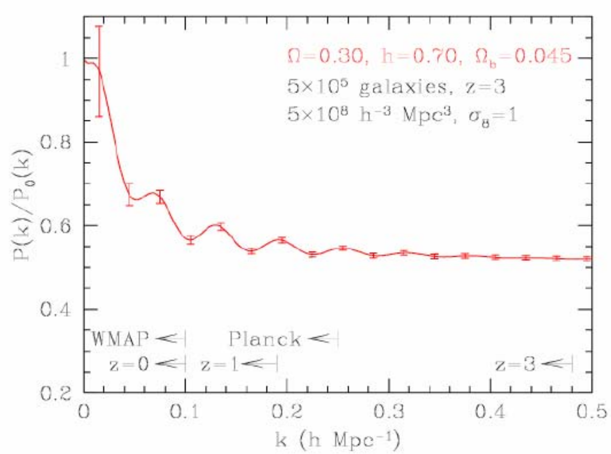
A Baseline Survey at $z = 1$



- 2,000,000 gal., $z = 0.5$ to 1.3
- 2000 sq. deg.
- 4×10^9 Mpc^3
- 0.3/sq. arcmin
- Linear regime $k<0.2h$ Mpc^{-1}
- 2-3 oscillations

Statistical Errors from the z=1 Survey

A Baseline Survey at $z = 3$



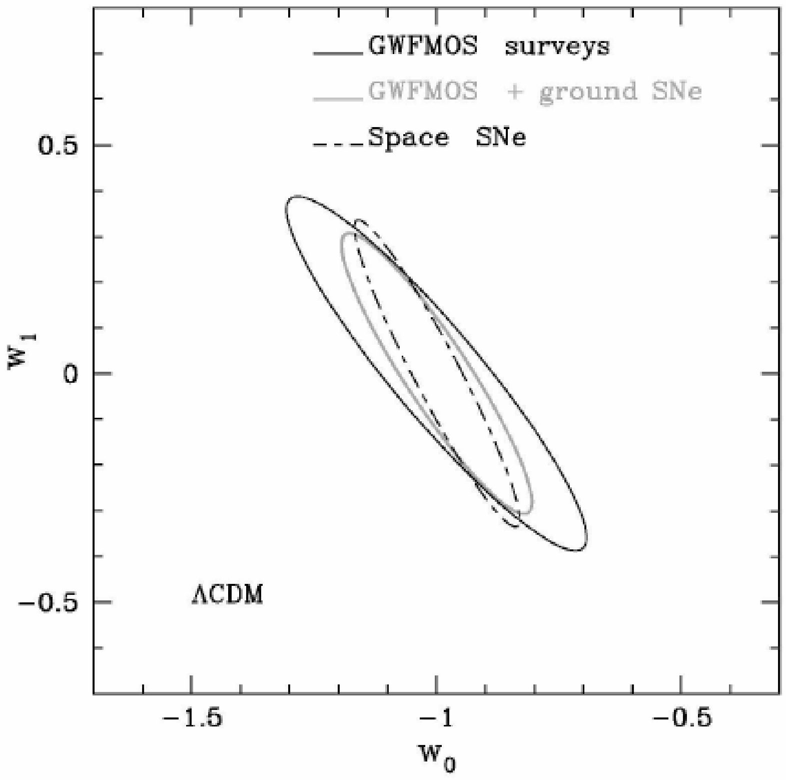
- 600,000 gal.
- ~300 sq. deg.
- 10^9 Mpc^3
- 0.6/sq. arcmin
- Linear regime $k<0.3h$ Mpc^{-1}
- 4 oscillations

Statistical Errors from the z=3 Survey

We need to go in the next generationod Snae/BAO/WL for w’

Results for ΛCDM

- Data sets:
  - CMB (*Planck*)
  - SDSS LRG (z=0.35)
  - Baseline z=1
  - Baseline z=3
  - SNe (1% in Δz=0.1 bins to z=1 for ground, 1.7 for space)
- $\sigma(\Omega_m) = 0.027$
  $\sigma(w) = 0.08$ at z=0.7
  $\sigma(dw/dz) = 0.26$
- $\sigma(w) = 0.05$ with ground SNe



Future Surveys WL

Survey	Diameter (m)	FOV (deg^2)	Area (deg^2)	start
DLS	2x4	2×0.3	28	1999
CFHTLS	3.6	1	172	2003
VST	2.6	1	x100	2006
Darkcam	4	2	10000	2008?
DES				
Pan-STARRS	4×1.8	4×4	31000	2008
LSST	8.4	7	30000	2012
DUNE	1.2	0.5	20000	2013
SNAP/JDEM	2	0.7	1000	2015

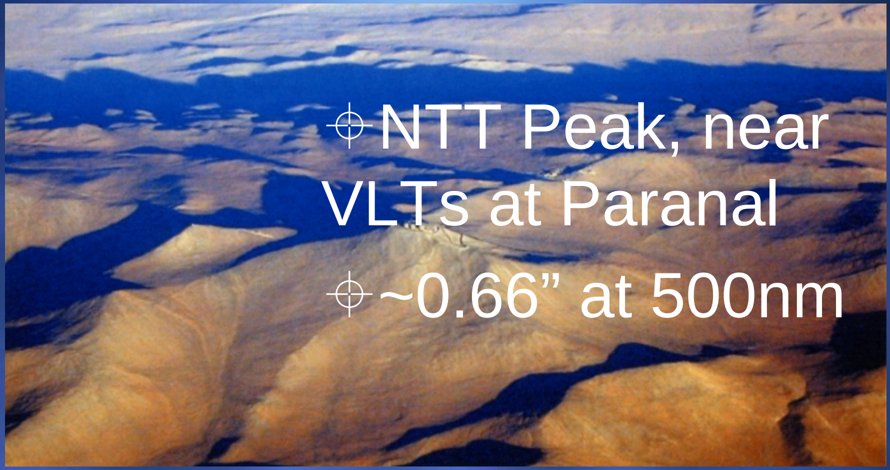
$\left.\begin{array}{l}\text{DUNE}\\ \text{SNAP/JDEM}\end{array}\right\}$ space

Also

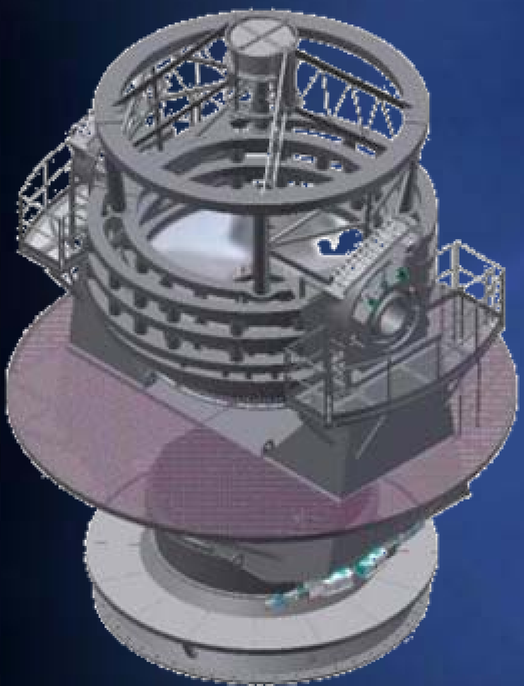
COSMOS/HST

A. Refregier Moriond 2006

darkCAM on VISTA



VISTA in 2007, will be a class wide field survey telescope, equipped with a near infrared camera (1.65 degree diameter field of view) containing 67 million 0.34 arcsec pixels and available broad band filters at Z,Y,J,H,K_s and a narrow band filter at 1.18 micron.

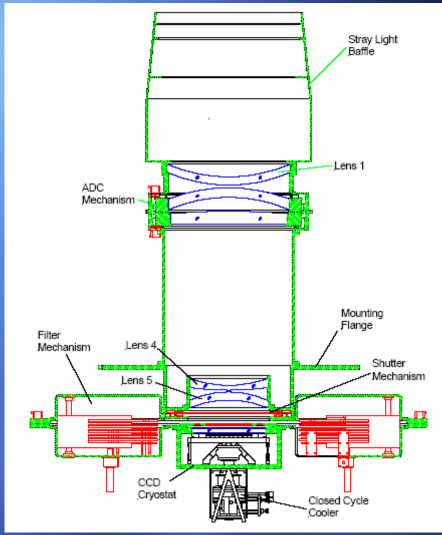


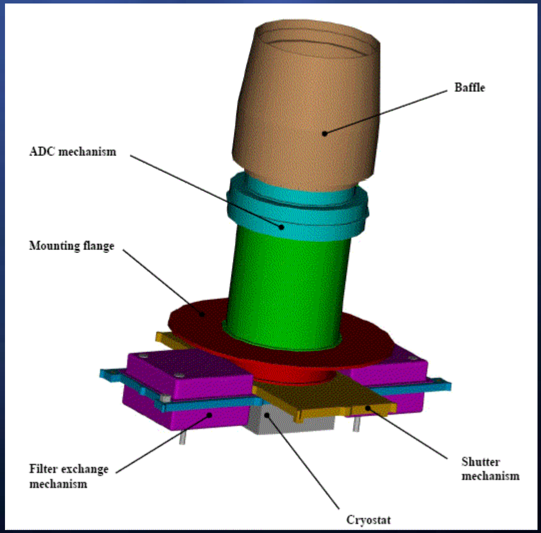
VISTA
(Visible & Infrared Survey Telescope for Astronomy)
4 metre mirror

Call for proposal surveys April 2006

darkCAM optical Camera

- 50 2k by 4k red-optimised CCDs
- 2 square degrees
- 0.23” pixels
- ADC, Filters in g’Vr’I’z’ (no U)
- Cost €15m
- Proposal to PPARC/ESO for 2009 start UK/French/German/Swiss collaboration (50% PPARC)
- Currently in difficulty: needs intervention on NTT dome (not approved by ESO)



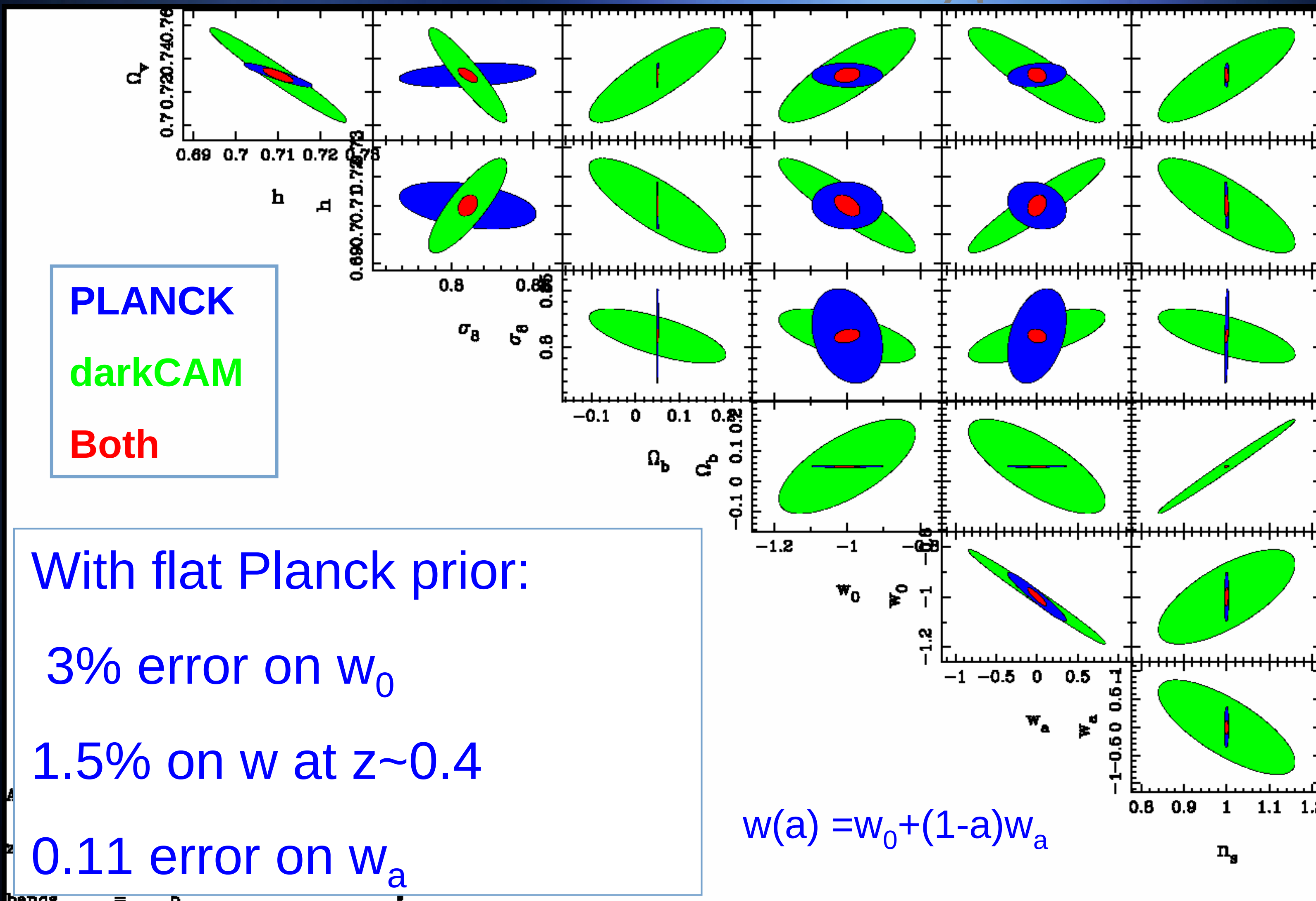


Proposed darkCAM survey

- 10000 square degrees with <z>=0.7
- Or 5000 square degrees with <z>=0.8
- 1000 square degrees may have 9-band photometry, with IR as well (not assumed)

- Lensing in 3D is very powerful: accuracies of ~2% on w potentially possible
- Synergy with DUNE in longer term

Expected errors from darkCAM survey: 3D shear transform (D_A and g)



With flat Planck prior:

3% error on w_0

1.5% on w at z~0.4

0.11 error on w_a

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

The DES Collaboration

61 scientists at 12 institutions

Fermilab: J. Annis, H. T. Diehl, S. Dodelson, J. Estrada, B. Flaugher, J. Frieman, S. Kent, H. Lin, P. Limon, K. W. Merritt, J. Peoples, V. Scarpine, A. Stebbins, C. Stoughton, D. Tucker, W. Wester.

University of Illinois at Urbana-Champaign: C. Beldica, R. Brunner, I. Karliner, J. Mohr, R. Plante, P. Ricker, M. Selen, J. Thaler

University of Chicago: J. Carlstrom, S. Dodelson, J. Frieman, M. Gladders*, W. Hu, E. Sheldon, R. Wechsler. * Carnegie Observatories until summer 2006

Lawrence Berkeley National Lab: G. Aldering, N. Roe, C. Bebek, M. Levi, S. Perlmutter

NOAO/CTIO: T. Abbott, C. Miller, C. Smith, N. Suntzeff, A. Walker

Institut d'Estudis Espacials de Catalunya: F. Castander, P. Fosalba, E. Gaztañaga, J. Miralda-Escude

Institut de Fisica d'Altes Energies: E. Fernández, M. Martínez

University College London: O. Lahav, P. Doel, M. Barlow, R. Bingham, S. Bridle, S. Viti, J. Weller

University of Cambridge: G. Efstathiou, R. McMahon, W. Sutherland

University of Edinburgh: J. Peacock

University of Portsmouth: R. Nichol

University of Michigan: R. Bernstein, A. Evrard, D. Gerdes, T. McKay

Barcelona Electronics/simulations, UK Optics/Science

The DES Experiments

The survey aims at the dark energy equation of state using four projects:

- Galaxy cluster counting
  - 12,000 clusters to z=1.3
  - Cluster-cluster correlation function
  - Cluster-shear correlation function
- Weak lensing
  - 300 million galaxies
  - Photo-z accuracy of $\delta z < 0.1$ to $z = 1$
  - 10-20 galaxies/sq-arcminute
- Galaxy angular clustering
  - 300 million galaxies
  - photo-z bins
  - baryon oscillation features
- Type 1a supernovae
  - 2000 supernovae
  - 10% time, 40 sq-degrees
  - 3 night revisit scale

Forecast Statistical Constraints on w

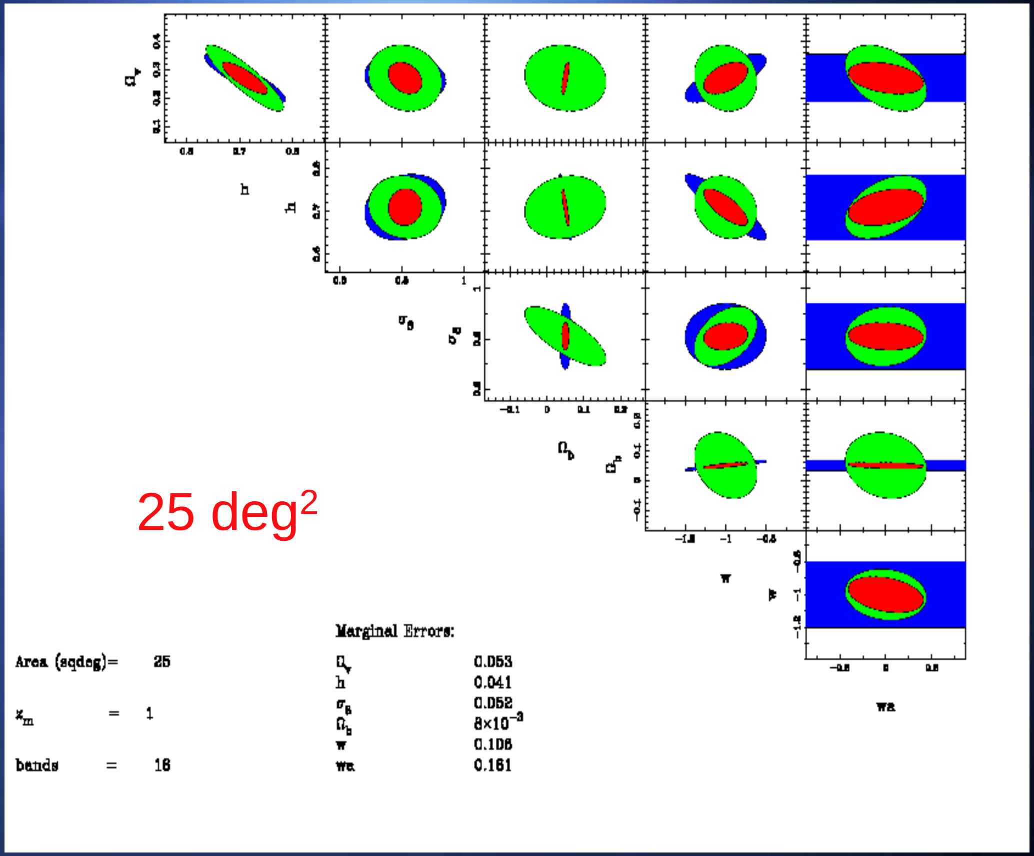
priors:	Uniform	WMAP	Planck
Cluster abundance: SZ clusters w/ WL mass calibration	0.09	0.08	0.02
Weak Lensing: shear-shear galaxy-shear + galaxy galaxy SS+GS+GG	0.15 0.08 0.03	0.05 0.05 0.03	0.05 0.05 0.02
Galaxy angular clustering	0.36	0.20	0.11
Supernovae Ia	0.34	0.15	0.04

Weller, Frieman, Hu, Lahev, Mohr, Lin, Annis, Smith, Gatzanaga, Peoples, Flaugher, Walker, Abbott...

Photo-z's underlie all of these:

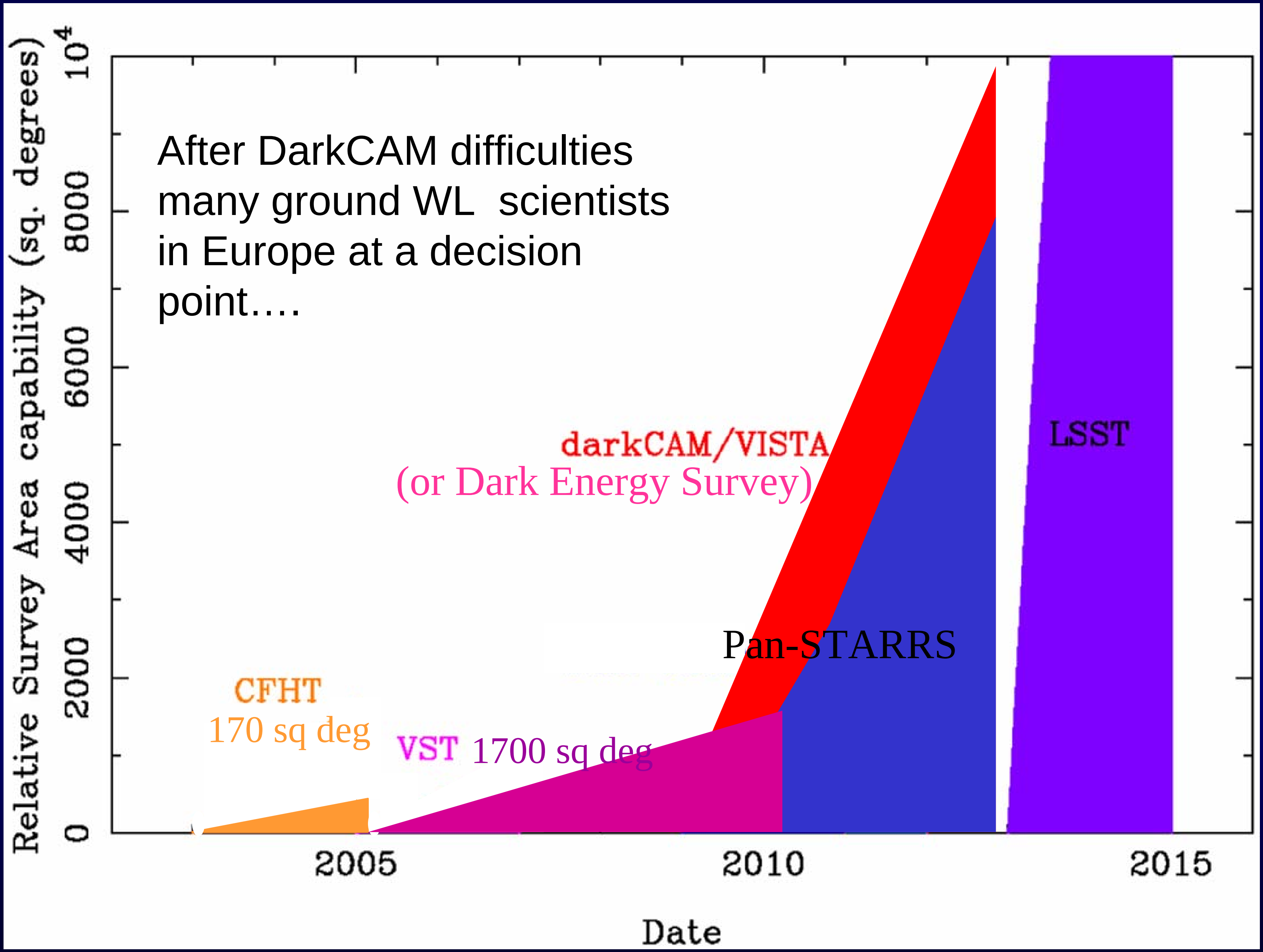
VST: VLT Survey Telescope

The VST is designed for Cassegrain operations, with a 1.5º diameter corrected fov, matched by a 16k x 16k CCD mosaic camera covering 1 x 1 square degree.



An alternative to DarkCAM: use the VLT Survey telescope (2.6 m) with a 5000 deg^2 survey…?

Current & Future Weak Lensing Surveys



ESA Missions in preparation

Corot
(CNES-ESA)
. 2006

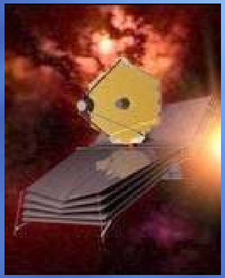
Venus Express
. 2005

Astro-F
(Japan-ESA)
2006

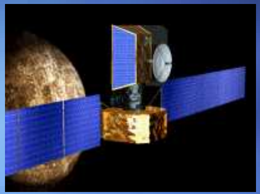
Herschel-Planck
2008

Microscope
(CNES-ESA)
2008

Lisa-
Pathfinder 2009



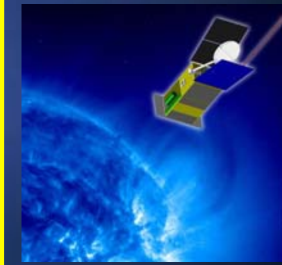
JWST
(NASA-ESA)
2011



Bepi-Colombo
2012

Gaia
2011-12

Lisa
2014



Solar
Orbiter
2015

2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015

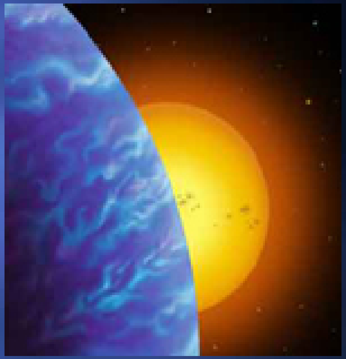
Cosmic Vision process

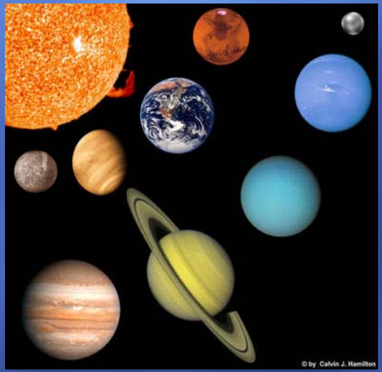
- ✓ **Cosmic Vision 2015 –2025 process launched April 04 with call for Science themes**
- ✓ **July 04: Analysis of responses by the ESA Science advisory bodies**
  - **Astronomy/Astrophysics (AWG)**
  - **Fundamental Physics (FPAG)**
  - **Solar System Science (SSWG)**
  - **Space Science Advisory Committee (SSAC) merged working group objectives into 4 grand themes**
- ✓ **May 05: Final Presentation of Cosmic Vision to SPC**

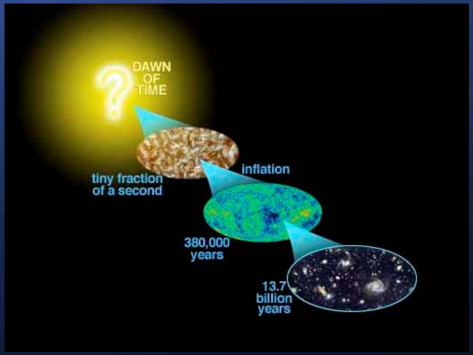
- ✓ May-June 2006 call for proposals (deadline 15 September 2006)
- ✓ End 2006 decision on a first set (5-6) passing to Phase 0
- ✓ End 2007 decision on 2 missions to pass to phase A (2 M€ each)
- ✓ End 2008 decision on one mission passing phase B/CD etc.
- ✓ Early 2009 Start of construction
- ✓ 2015 Launch of a the first mission (enveloppe 320 M€ investment)

Grand themes

1. What are the conditions for life and planetary formation?
2. How does the Solar System work?
3. What are the fundamental laws of the Universe?
4. How did the Universe originate and what is it made of?







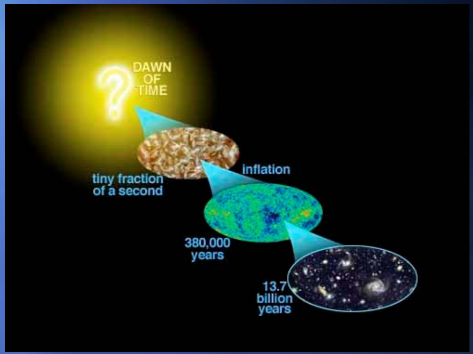
4. How did the Universe originate and what is it made of?

4.1 The early Universe

Imprints of inflation are related to the polarization parameters of anisotropies of the Cosmic Microwave Background (CMB) due to primordial gravitational waves from Big Bang.

Dark energy can be studied in the gravitational lensing from cosmic large scale structures and the measurement of the luminosity-redshift relation of distant Supernovae (SN) Ia.

Tools: All-sky CMB polarisation mapper, **Wide-field optical-near IR imager.** Later: Gravitational Wave Cosmic Surveyor



Missions 2015-2025

Probe dark energy from high Z SNIa and weak lensing

OPTICAL-NIR WIDE FIELD IMAGER

Probe inflation from shape of the primordial fluctuations

ALL SKY CMB

POLARIZATION MAPPER

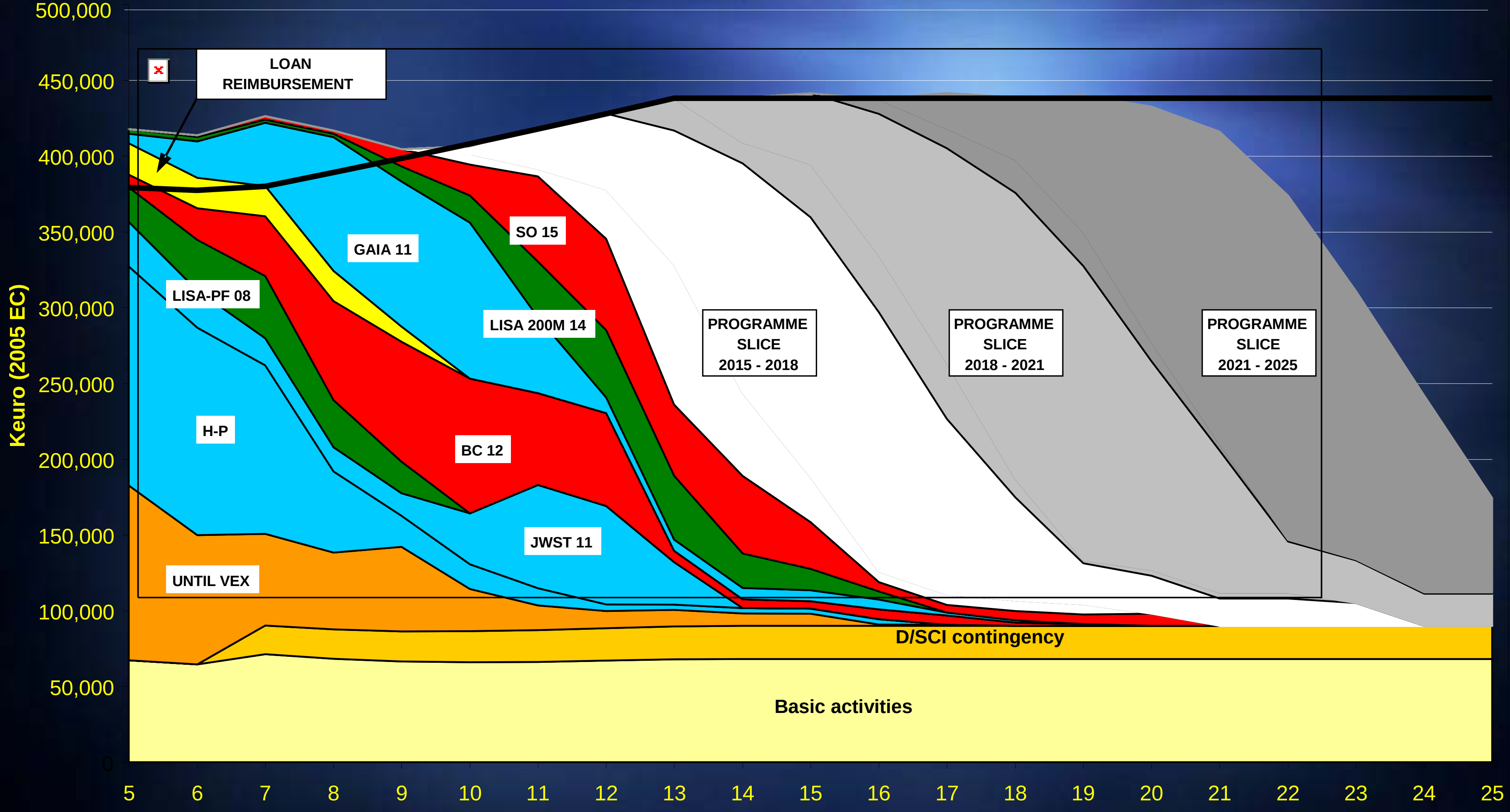
4.2 The Universe taking shape

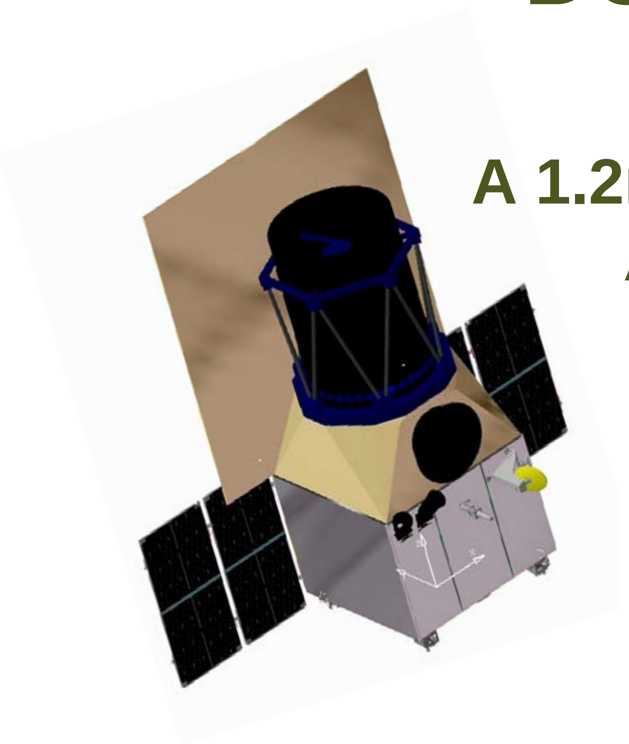
4.3 The evolving violent Universe

ESA funding level and strategy

- The ESA Council meeting at Ministerial level in December 2005 decided to maintain the present Science Programme Level of Ressources with inflation correction to 2006. From 2007, it approved a 5 year annual increase of 2.4% over the current LoR
- Uncertainties:
  - The envelopes of GAIA, BepiColombo LISA and SO and their impact on the future programme.
  - The launcher for JWST.
- ESA will implement the major objectives of Cosmic Vision 2015-2025 while keeping flexibility of planning, through <u>slices</u>
- The first Call for Mission Proposals to cover first slice (2015 – 2018). Next slices to be implemented through subsequent Calls.

COSMIC VISION 2015 - 2025
ESA Corridor Planning
Three programme slices





DUNE: The Dark Universe Explorer

A 1.2m space telescope with 0,5 deg^2 FOV

Alexandre Réfrégier (CEA Saclay)
CEA Saclay, CNRS(IAP, IN2P3, LAM)

QuickTime™ et un
décompresseur TIFF (LZW)
sont requis pour visionner cette image.

Requirements for Weak Lensing

dapnia

cea

saclay

Statistical Requirements:

• a 20,000 deg^2 survey at high galactic latitude (|b|>30° deg)

• sample of at least 35 galaxies/$amin^2$ usable for weak lensing with a median z~1 and an rms shear error per galaxy of $\sigma\gamma$=0.35 (or equivalent combination)

• a PSF FWHM smaller than 0.23''

•photometric redshifts to derive 3 redshift bins over the survey area (from ground based observations, type DarkCAM)

Systematics Requirements:

•a precision in the measurement of the shear after deconvolution of the PSF better than about 0.1%.

• good image quality: low cosmic ray levels, reduced stray light, linear and stable CCDs, achromatic optics

• Photometric redshifts with precision $\Delta z<0.1$ in a subset of the survey to place limits on the intrinsic correlations of galaxy shapes (from ground based observations)

Requirements for Supernovae

dapnia
cea
saclay

Statistical Requirements:

- Survey 2×[60 deg^2 in 2 distinct regions for 9 months], yielding ~10000 Type Ia supernovae out to z~1
- Measurement of rest frame U and B peak luminosity with an average of 2% statistical uncertainties. This can be achieved by measurements in UBVRIZ bands of supernovae light curves every 4 days.
- Identification of supernovae from their multi-color light curves. This requires photometric measurement of at least 2 rest frame bands, from about 2 weeks rest frame before maximum to about 3 weeks rest frame after maximum light.
- Spectroscopic redshift of the supernovae host galaxies (differed and from the ground)

Systematics Requirements:

- Control systematics such as, malmquist bias, extinction by host galaxy, evolution of the supernovae luminosity and gravitational lensing to an average level of ~ 2% per Δz =0.1 bin. This requires precise photometry of the supernovae lightcurves in at least 3 bands from 2 weeks rest frame before maximum to about 6 weeks rest frame past maximum.

Science Requirements

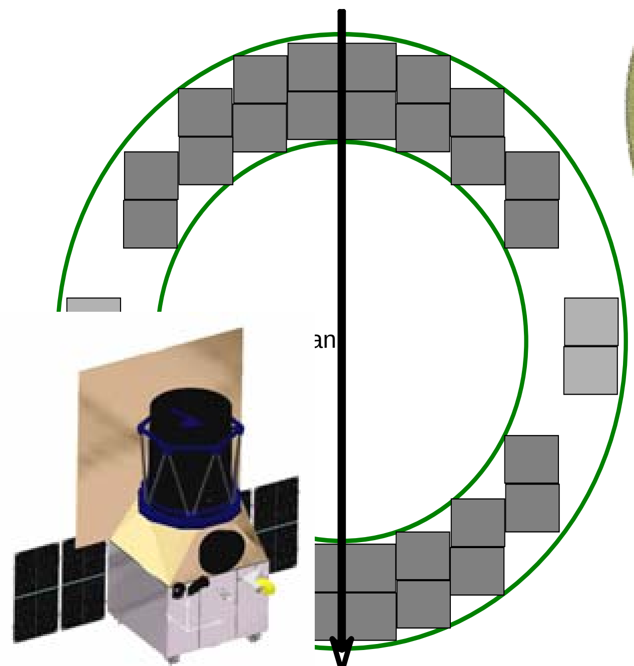
Weak lensing

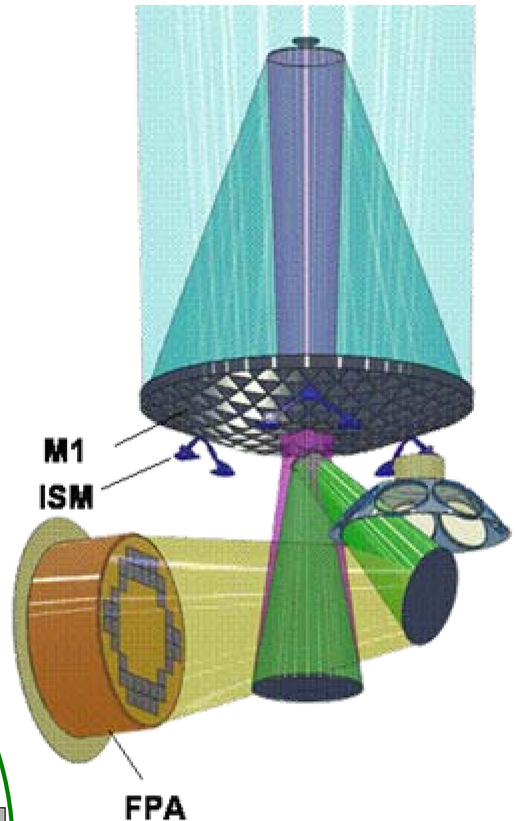
RIz band	0.783 µm +/- 0.217 µm
PSF FWHM	0.23 arcsec
Resolution	FWHM=2 pixels
Scanned field	|Latitude|>30°
SNR for galaxy Mag=25.0	> 7
Mission length	2.5 – 3 years
PSF ellipticity	~ 2-3 % (relaxed to 6%)
PSF stability	0.1 %

SuperNovae option

Scanned field	2*60deg^2
Mission length	2*9 months
6 filters	UB, 4 UB redshited bands
SNR for SN with redshift=1.0	> 4.5 - 5

GAIA CCD parameters	
CCD AL	49.4 mm
CCD AC	60.3 mm
Example of parameters in TDI mode	
CCD number in AL direction	4
Integration time per CCD	375 s
Science CCD number	32
Spin period	16.3 days
Effective field of view	0.47 deg^2
Mission length	2.72 years



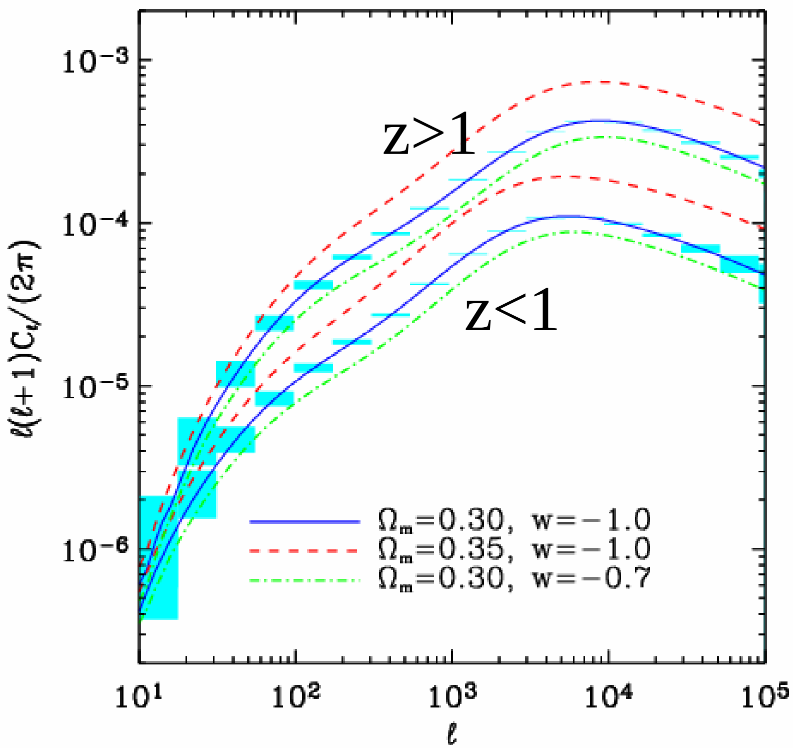


Weak Lensing Power Spectrum Tomography

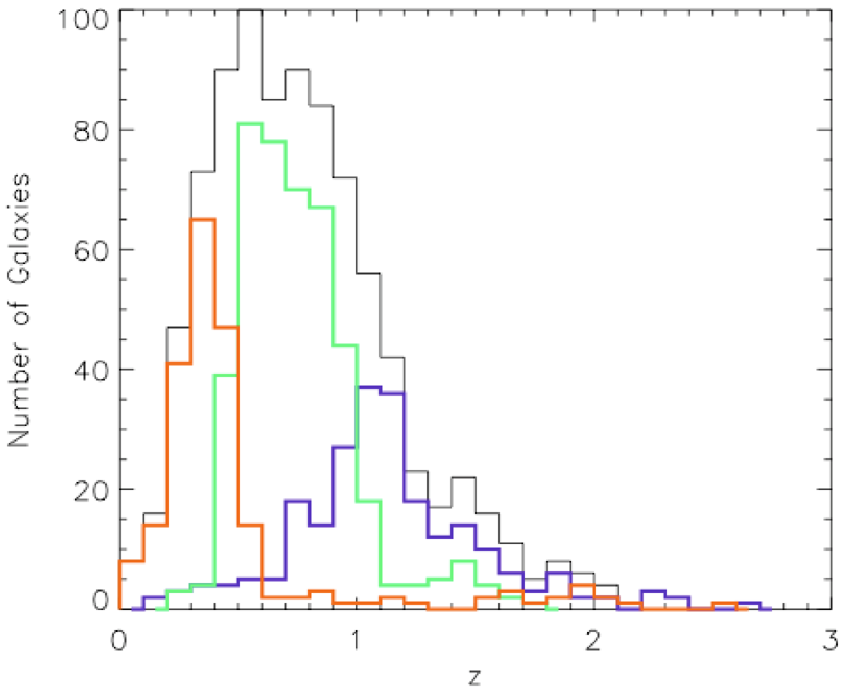
dapnia
cea
saclay

DUNE baseline: 20,000 deg^2, 35 galaxies/amin^2, ground-based photometry for photo-z's, 3 year WL survey

WL power spectrum for each z-bin



Redshift bins from photo-z's



Constraints on Dark Energy I

dapnia

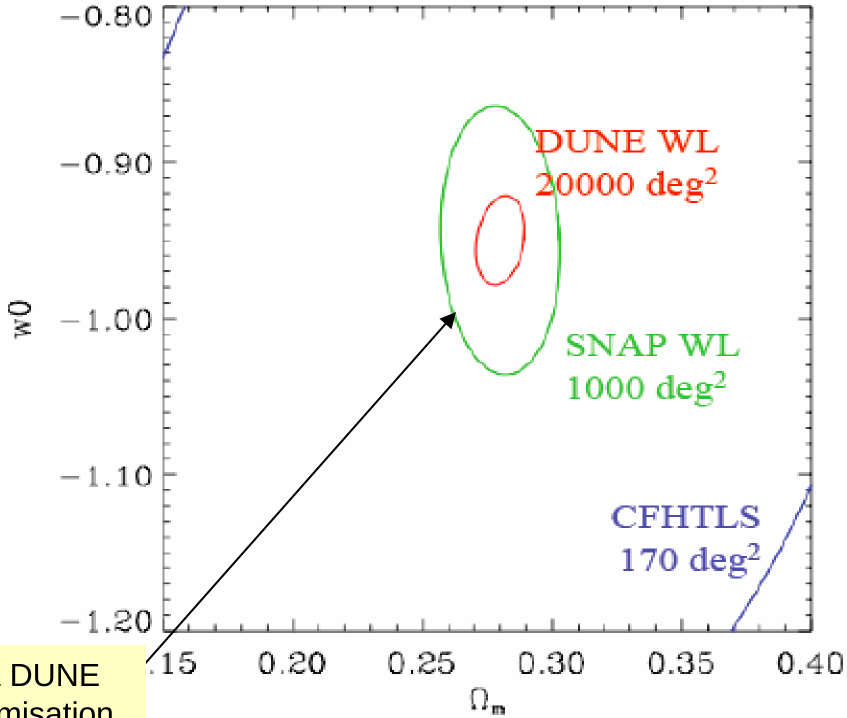
cea

Weak Lensing:

C_1 measurement in 3 z-bins

Photo-z errors of Δz=0.1

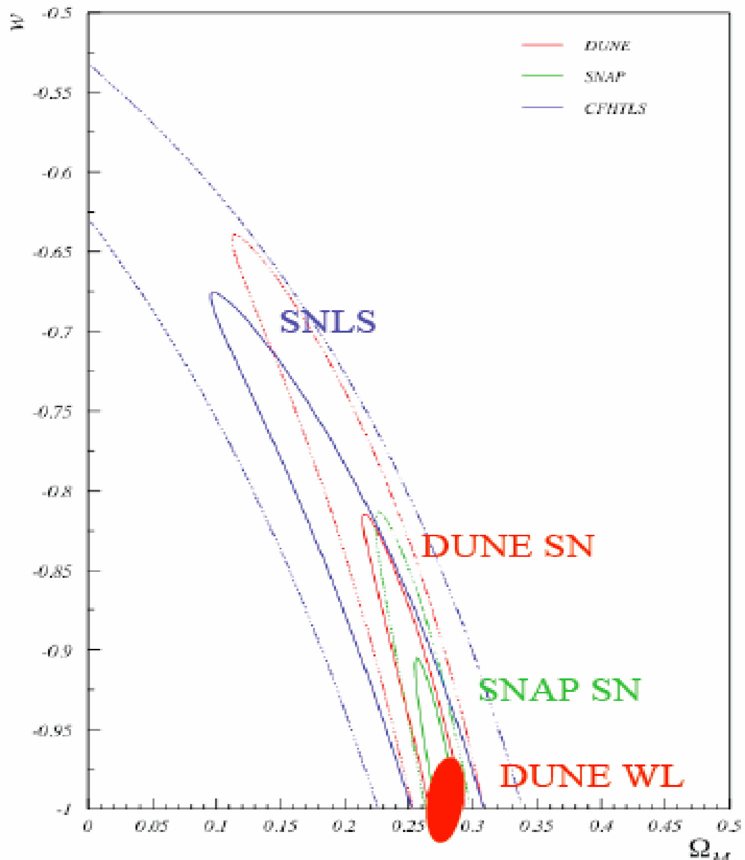
No priors (8 parameters)



By Amara et al.

Supernovae:

Prior: w=constant



By Pain, Kroely, Astier, Antilogus, Barrelet et al.

At a DUNE optimisation point

Not yet checked by SNAP.

One of the possible methods

Dark energy evolution: $w(a)=w_0+(a_n-a)w_a$, $a_n=0.6$ assume a flat universe

Constraints on Dark Energy II

dapnia

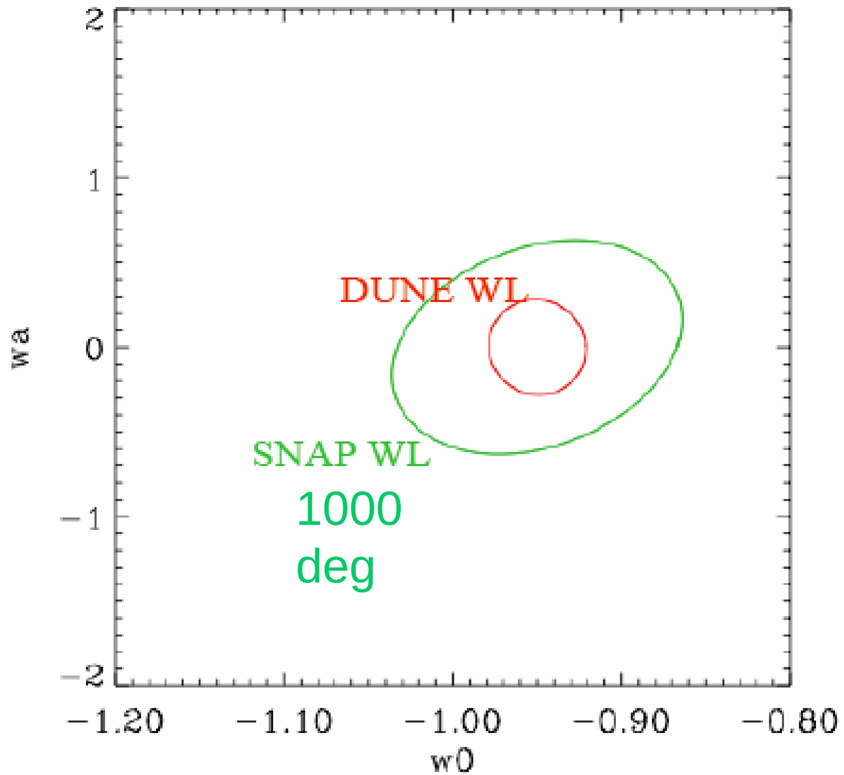
cea

Weak Lensing:

C_l measurement in 3 z-bins

Photo-z errors of Δz=0.1

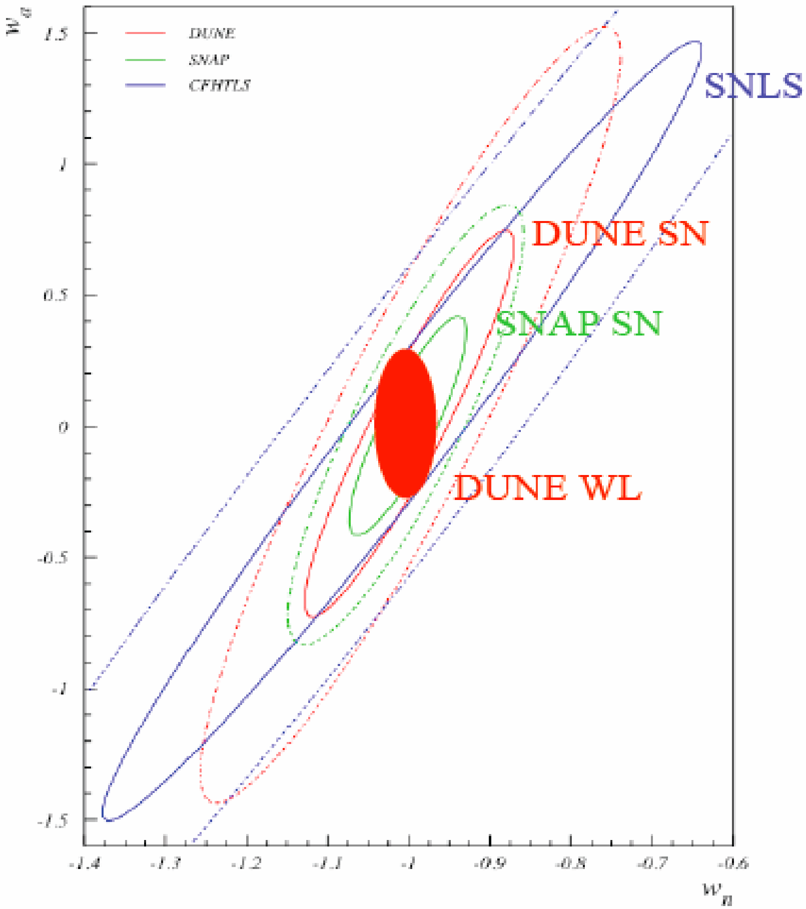
No priors



By Amara et al.

Supernovae:

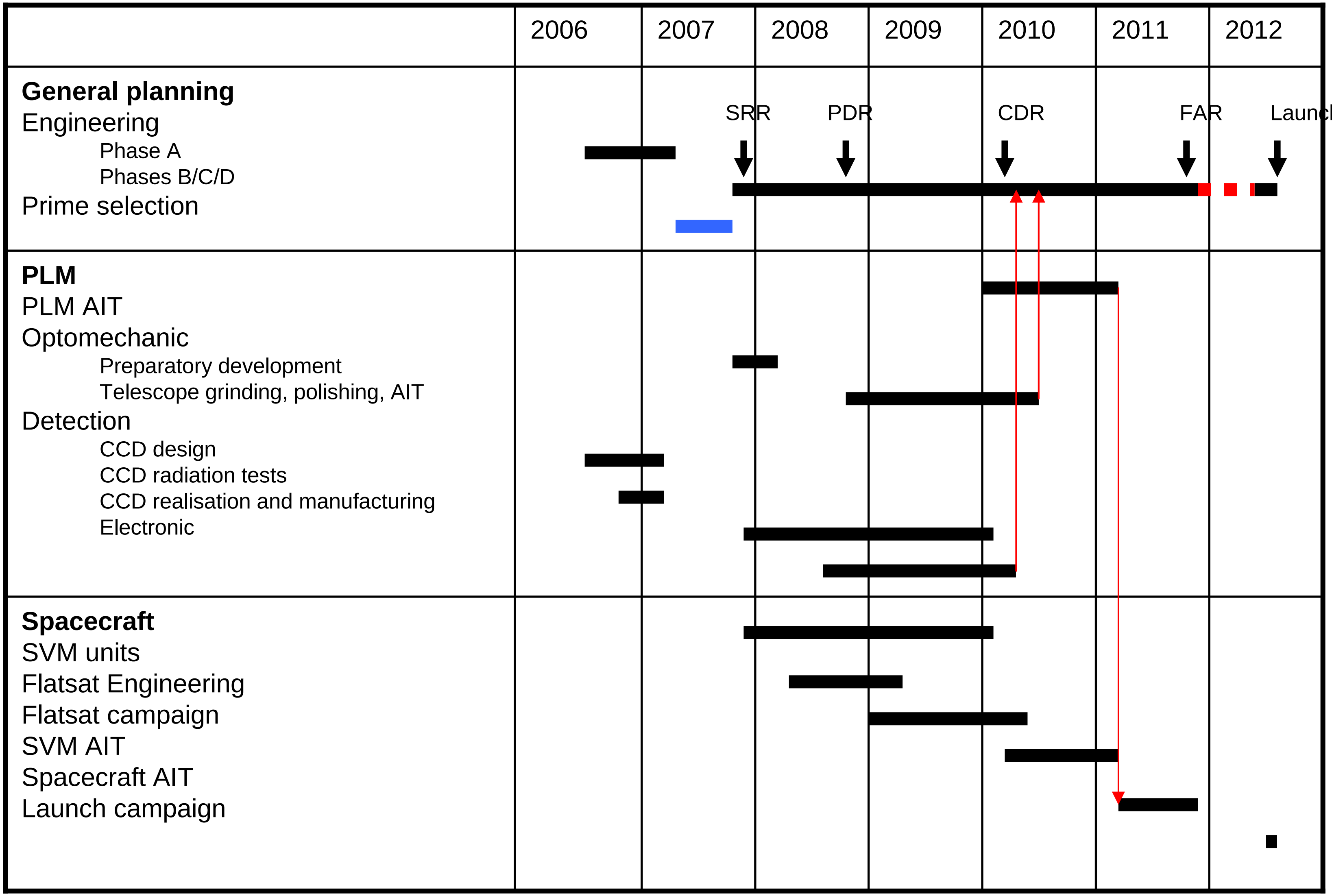
Prior: $\Delta\Omega_m$=0.03



By Pain, Kroely, Astier, Antilogus , Barrelet et al.

Dark energy evolution: $w(a)=w_0+(a_n-a)w_a$, $a_n=0.6$ assume a flat universe

Overall Schedule



Cost 300 M€ investment, 500 myears, beyond CNES budget forwarded as a possible first ESA mission for launch 2015, an IR possibility has emmerged as a consequence of the delay

SNAP Collaboration

LBNL	G. Aldering, S. Bailey, C. Bebek, W. Carithers, T. Davis†, K. Dawson, C. Day, R. DiGennaro, S. Deustua†, D. Groom, M. Hoff, S. Holland, D. Huterer†, A. Karcher, A. Kim, W. Kolbe, W. Kramer, B. Krieger, G. Kushner, N. Kuznetsova, R. Lafever, J. Lamoureux, M. Levi, S. Loken, B. McGinnis, R. Miquel, P. Nugent, H. Oluseyi†, N. Palaio, S. Perlmutter, N. Roe, H. Shukla, A. Spadafora, H. Von Der Lippe, J-P. Walder, G. Wang
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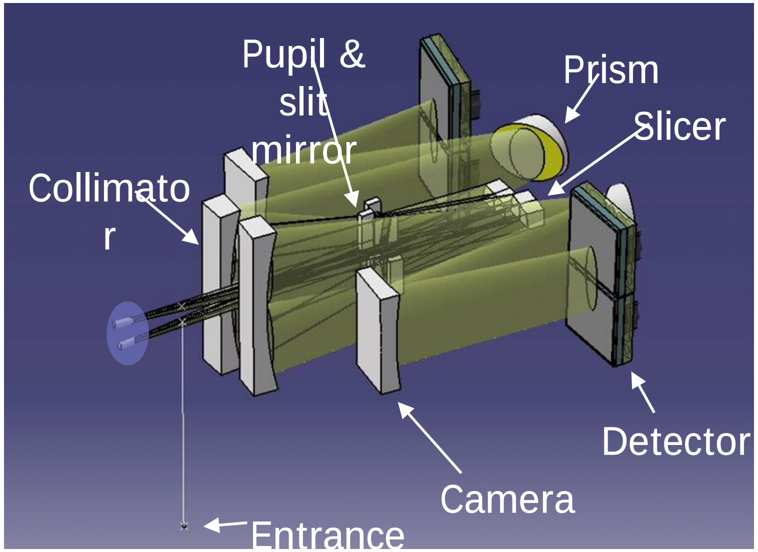
Caltech	J. Albert, R. Ellis, R. Massey†, A. Refregier†, J. Rhodes, R. Smith, K. Taylor, A. Weintein
Fermi National Laboratory	J. Annis, F. DeJongh, S. Dodelson, T. Diehl, J. Frieman, D. Holz†, L. Hui, S. Kent, P. Limon, J. Marriner, H. Lin, J. Peoples, V. Scarpine, A. Stebbins, C. Stoughton, D. Tucker, W. Wester
Indiana U.	C. Bower, N. Mostek, J. Musser, S. Mufson
IN2P3-Paris -Marseille	P. Astier, E. Barrelet, R. Pain, G. Smadja†, D. Vincent A. Bonissent, A. Ealet, D. Fouchez, A. Tilquin
JPL	D. Cole, M. Frerking, J. Rhodes, M. Seiffert
LAM (France)	S. Basa, R. Malina, A. Mazure, E. Prieto
University of Michigan	B. Bigelow, M. Brown, M. Campbell, D. Gerdes, W. Lorenzon, T. McKay, S. McKee, M. Schubnell, G. Tarle, A. Tomasch
University of Pennsylvania	G. Bernstein, L. Gladney, B. Jain, D. Rusin
University of Stockholm	R. Amanullah, L. Bergström, A. Goobar, E. Mörtsell
SLAC	W. Althouse, R. Blandford, W. Craig, S. Kahn, M. Huffer, P. Marshall
STScI	R. Bohlin, D. Figer, A. Fruchter

snap.lbl.gov

An IFU slicer spectrometer for SNAP

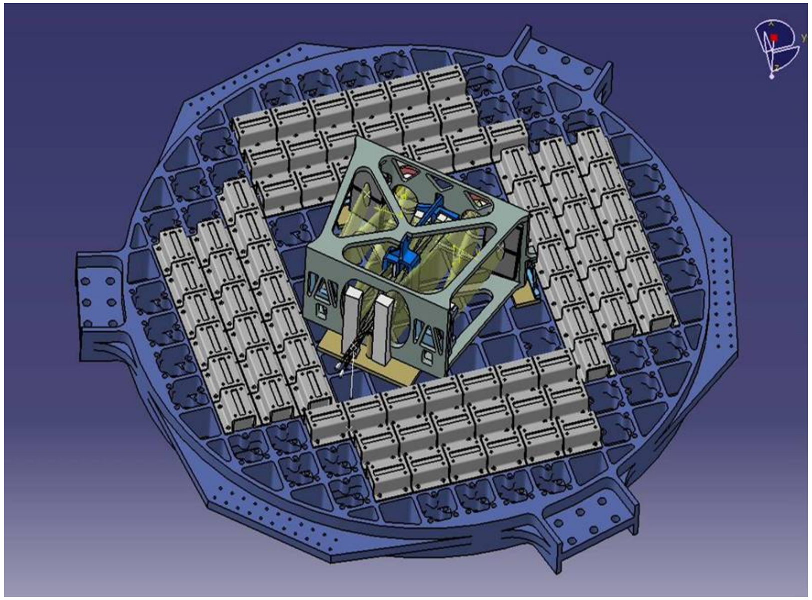


- IFU slicer concept
- Compact and light (20x30x10 cm)
- Galaxy and SN spectrum at the same time

Development in France, Marseille

CNRS (IN2P3,INSU)

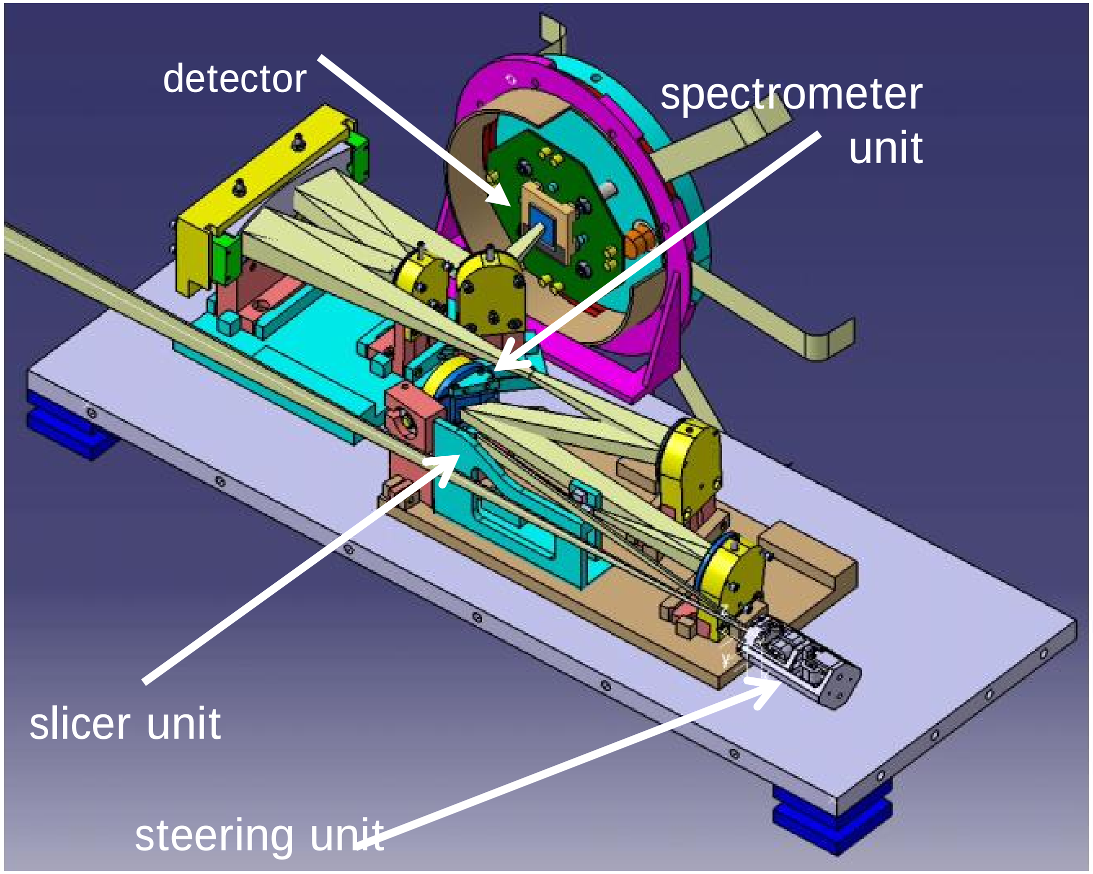
	Visible	IR
Wavelength coverage (μm)	**0.35-0.98**	**0.98-1.70**
Field of view	**3.0" / 6.0"**	**3.0" / 6.0"**
Spectral resolution, λ/δλ	**70-200**	**70-100**
Spatial resolution element (arc sec)	**0.15**	**0.15**
detectors	**LBL CCD 10 μm**	**HgCdTe 18 μm**
Efficiency with OTA and QE	**>50%**	**>40%**



R&D: Spectrometer demonstrator

A SNAP demonstration spectrometer assembly is going on ...

- Build a complete spectrometer with new slicer design and SNAP specifications
- Prove SNAP requirements for spectro-photometric performances
- include fabrication and testing
- test both in room T° and cold T°
- Validate and tune the simulation



Well in phase with the SNAP instrument

Same optical design

Same characteristics (PSF, sampling ..)

Validation in visible and IR range.

Funded by CNRS (IN2P3 / INSU), CNES and Berkeley university

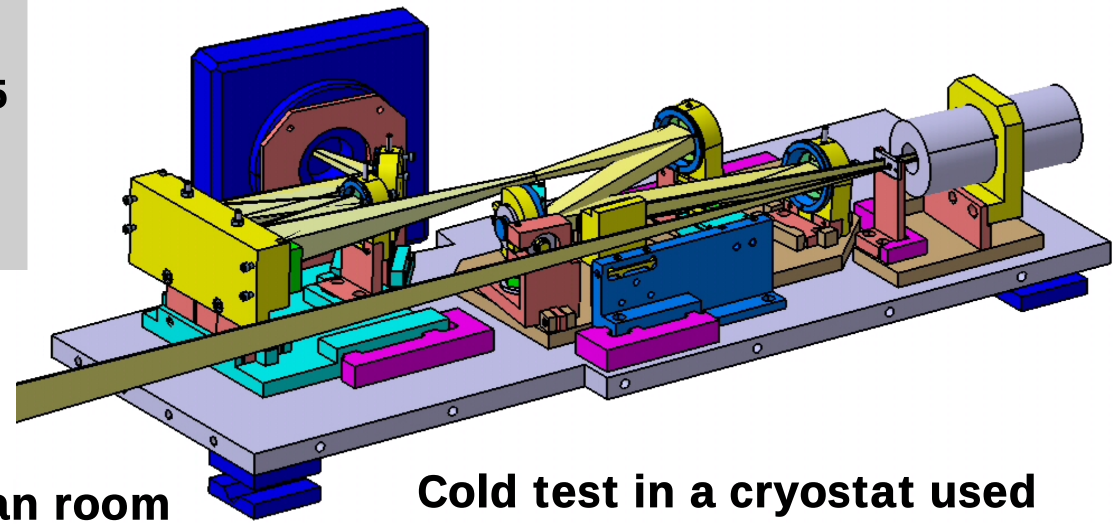
R&D : SNAP Spectrograph demonstrator

Concept done

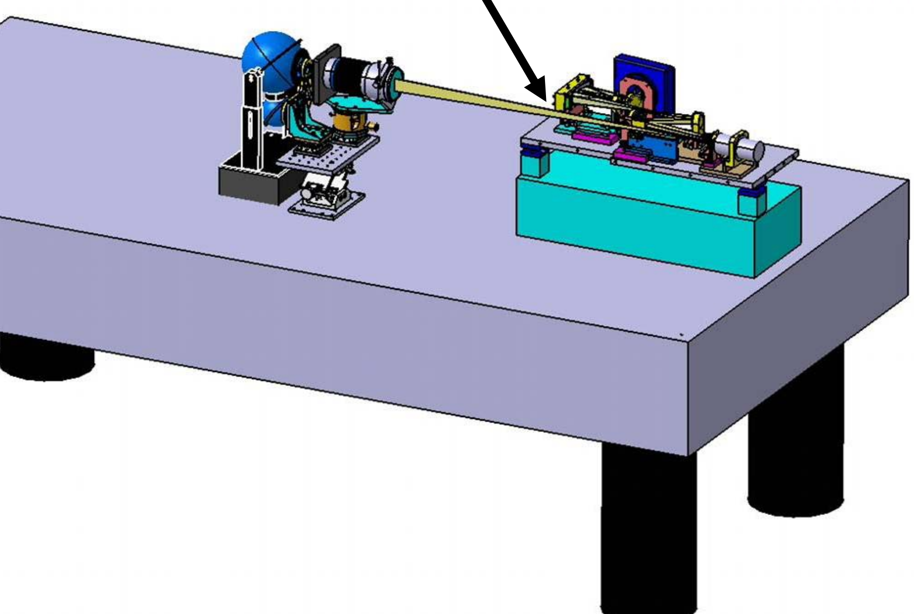
Technical review passed in Nov 05

Manufacturing started

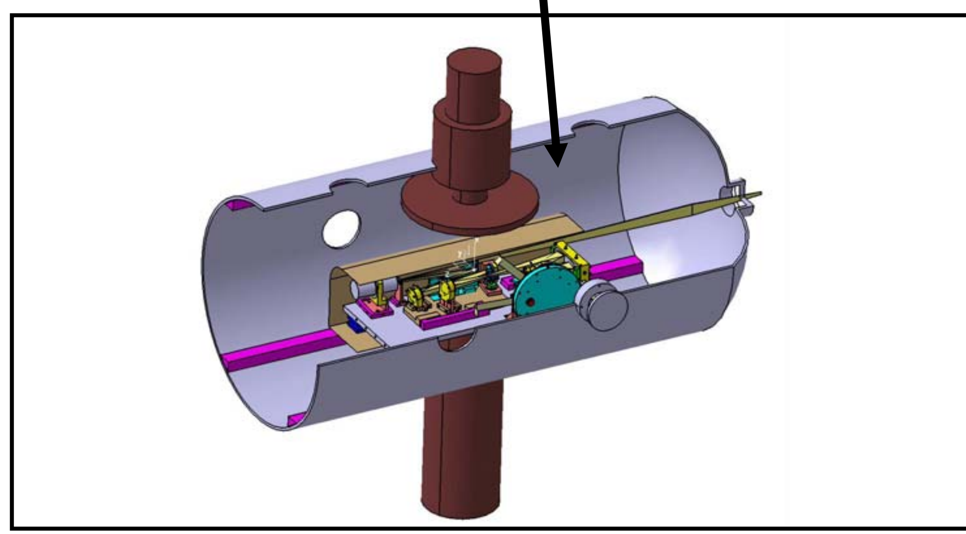
Integration and test for end 2006



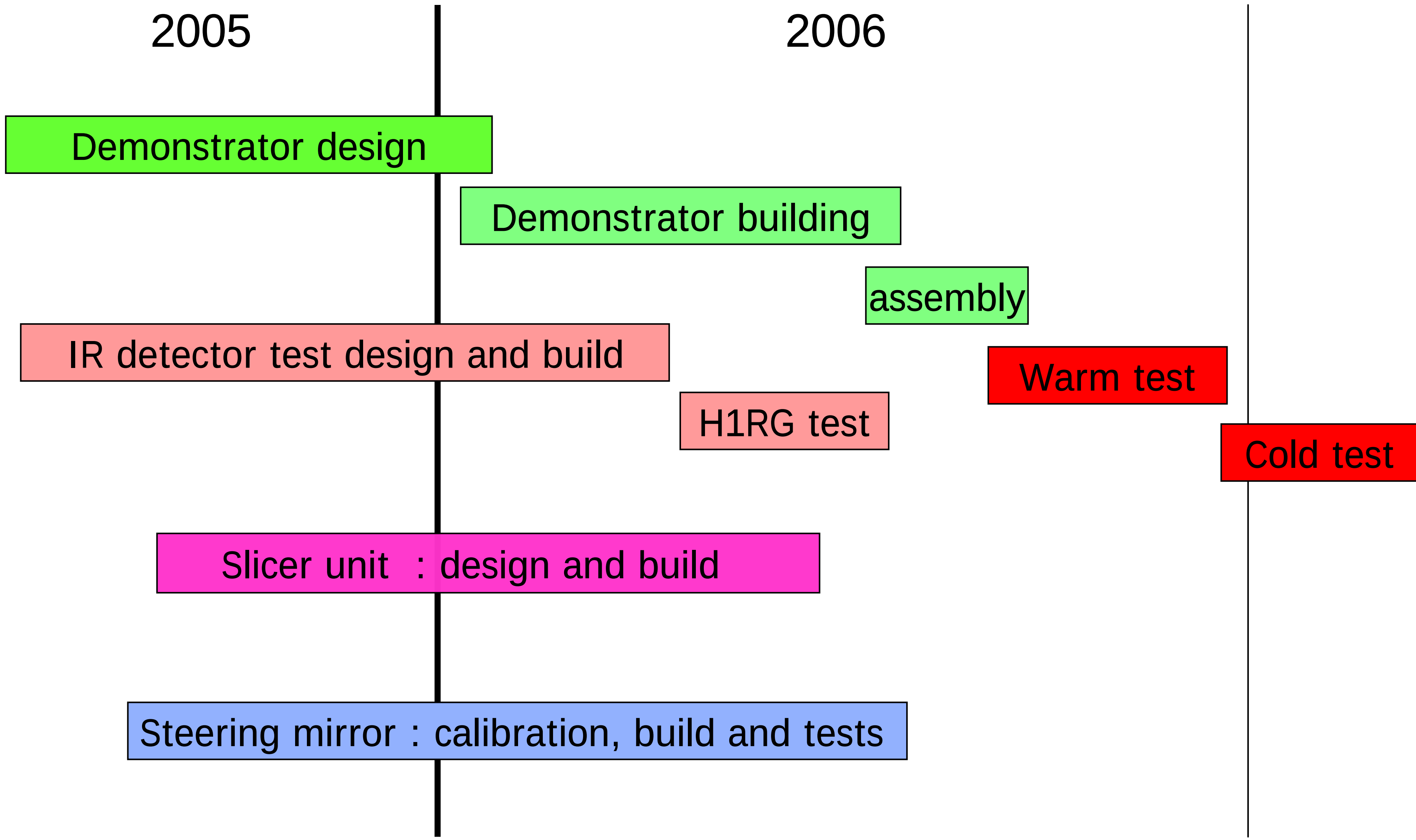
Warm tests in a dedicated clean room



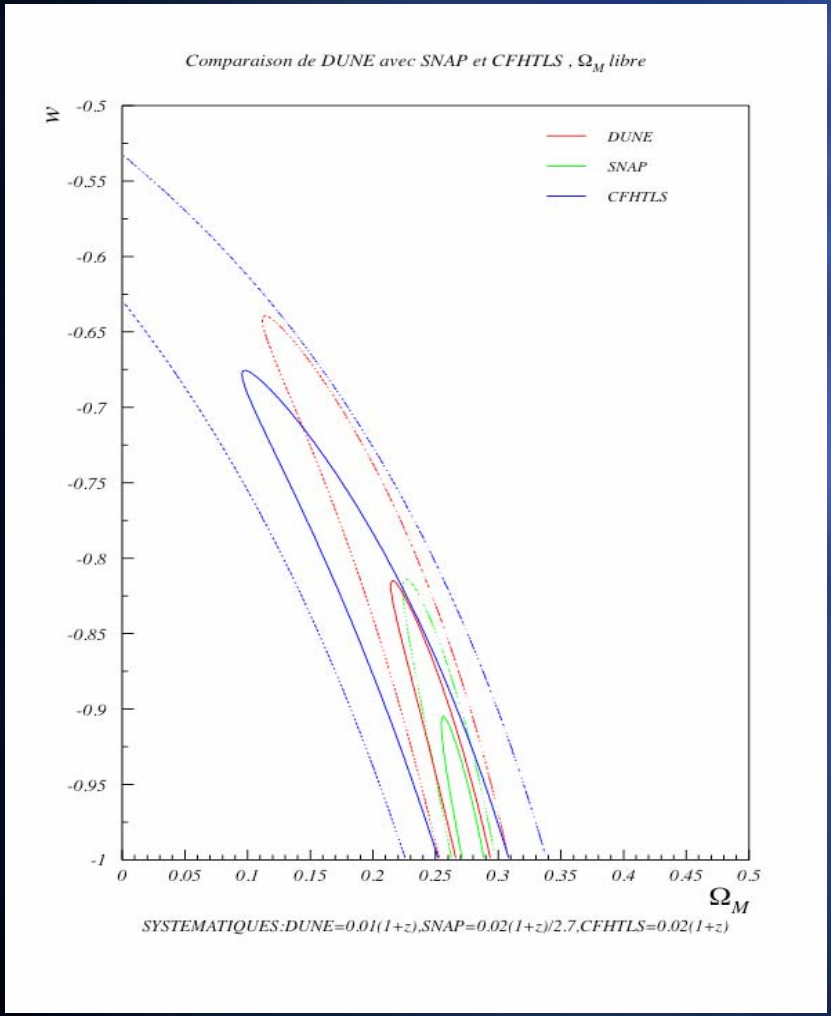
Cold test in a cryostat used currently for Herschel in LAM

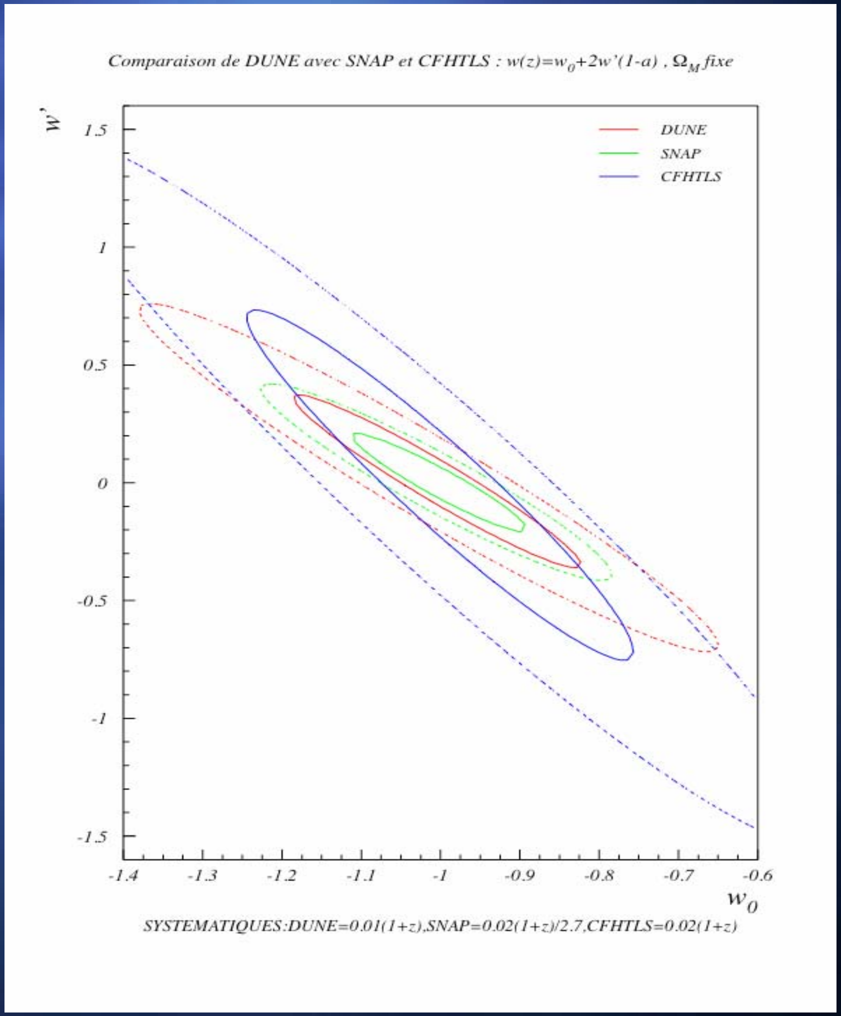


Demonstrator schedule



SNLS vs DUNE vs SNAP





R.Pain

Conclusions (ground)

- There is currently a strong program in Europe for dark energy on Snae (SNLS,SNIFS) in collaboration with US
  - It will obtain a measurement of w at 5% in a few years (+BAO)
- The BAO program has also a more or less clear roadmap
- On the WL front,
  - the study of systematics increases in maturity and will hopefully soon start giving complementary constraints to the other methods
  - the difficulties of DarkCAM reorient the major choices to VST and DES while other programs are in progress (e.g COMBO-17, COSMOS/HST)
- Roadmapping for ground projects is ongoing, in astrophysics community (ASTRONET). A lot of discussions in the particle physics (CERN Strategy group) and astroparticle (ApPEC/ASPERA) communities for the implication of dark energy in their roadmap.

Roadmap for particle and astroparticle physics

- 2 instances: CERN strategy group+ ApPEC
  - CERN strategy group roadmap ready by mid-july (next meeting in Berlin 2nd of May, R. Staffin present) Role of Dark energy?
  - ApPEC Roadmap also ready by mid-summer.
    - 6 large infrastructures considered:
      - KM3, CTA, GWA,
      - 1ton DM, 1tonDBD,
      - Large underground detector….
    - Discussions on whether Dark Energy should be part of the roadmap
- ASTRONET (astrophysics+cosmology) strategic plan, will take 1-2 years

Conclusions (space)

- The ESA Cosmic Vision process permits the launching of a medium range mission by 2015
  - A large telescope with near-IR capabilities is part of the call
  - A dark energy mission (DUNE) will be proposed in the ESA process, upgraded in IR?
  - Ongoing common work between LBL, CNES, INSU and IN2P3 on the spectrograph of SNAP (other synergies possible e.g SiC mirror)
  - The physics of SNAP is a high priority for IN2P3/CNRS
  - DOE-CNES contacts concerning SNAP are foreseen in the very near future….
- Should we not learn from PLANCK and LISA and go for a US-European (ESA or one or two nations) mission on dark energy?

Thank you