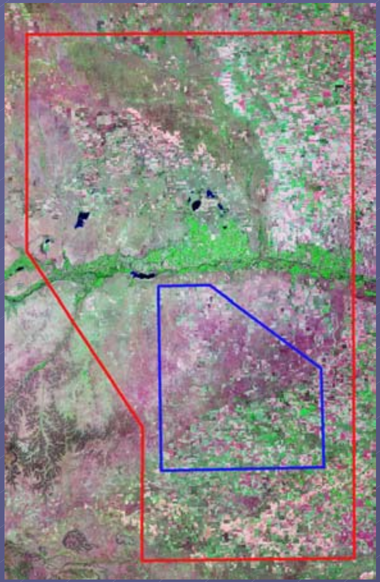
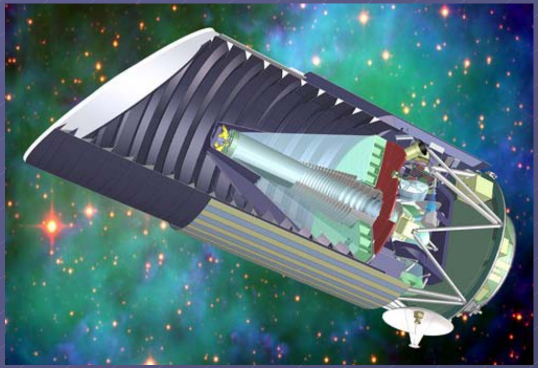
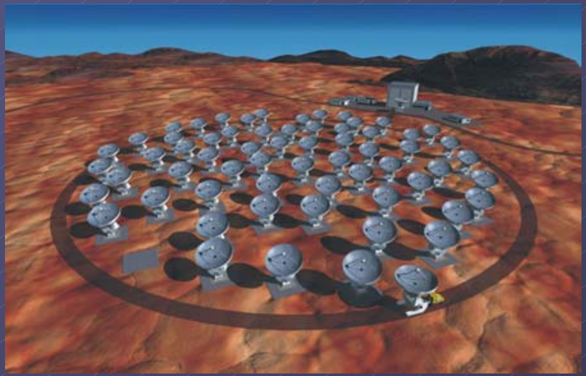
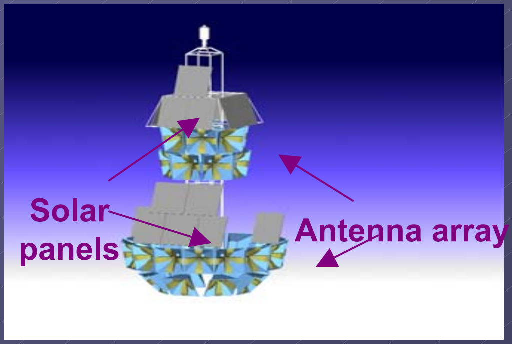
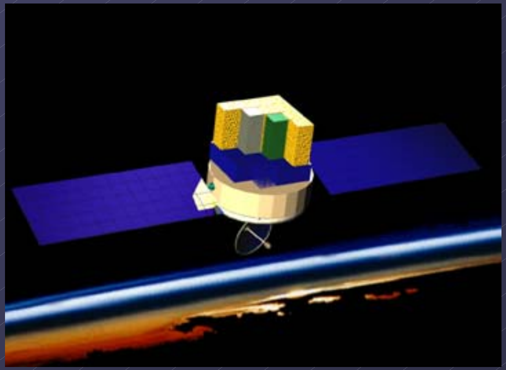
Future Facilities in Astroparticle Physics & Cosmology

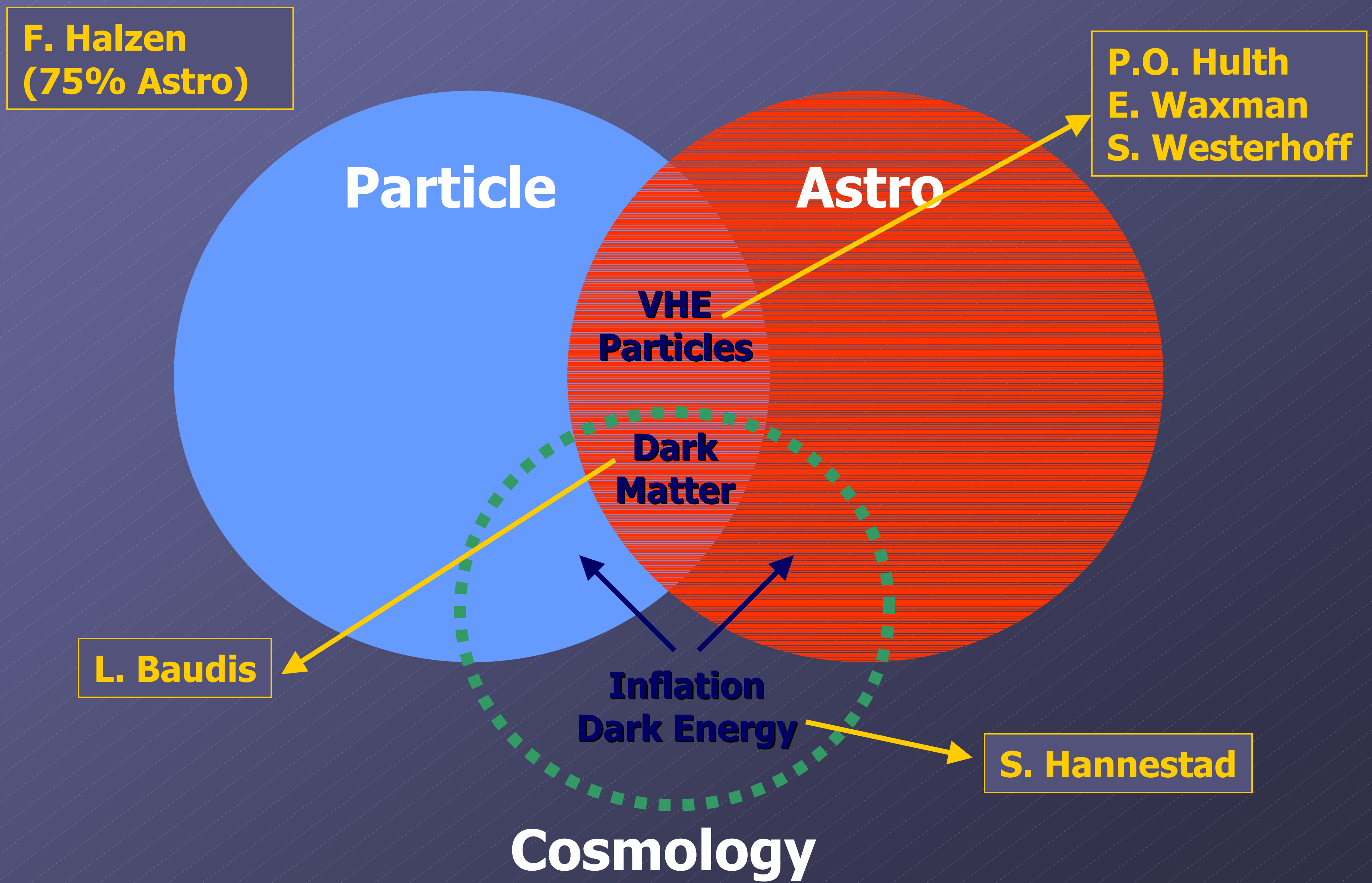





Lepton Photon
04 July 2005

Rene A. Ong
Univ. of California, Los Angeles

Science


F. Halzen
(75% Astro)
P.O. Hulth
E. Waxman
S. Westerhoff
Particle
Astro
VHE
Particles
Dark
Matter
L. Baudis
Inflation
Dark Energy
S. Hannestad
Cosmology

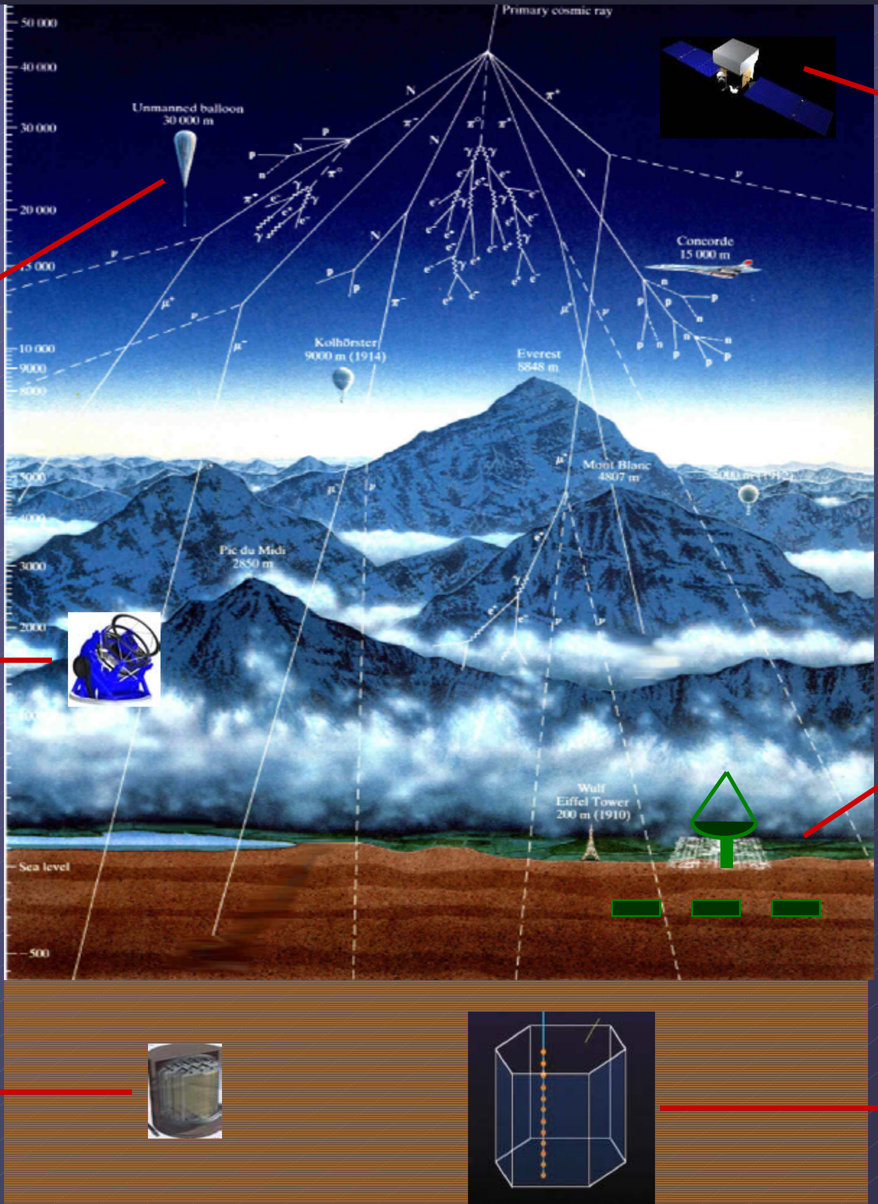
Messengers

We learn about the Universe from:

Particle	Charge	Astrophysical examples
Photon	neutral	CMB, O/IR, X-ray, γ-ray
Cosmic ray	charged	UHE CR's
Neutrino	neutral	relic, solar, SN, UHE
Grav. Wave	neutral	(not covered here)
New particle	??	WIMP …

Techniques

A myriad of techniques !



Satellite: CMB, O/IR, γ-ray

Balloon: CMB, ν

Ground: CMB, O/IR

Air Shower: γ-ray, CR, ν

Underground: Dark matter

Underground: ν

Outline

- Introduction: science & messengers
- Top recent discoveries

Future:

- General Trends
  - Remarkable variety & number of projects.
- Briefly discuss each field:
  - Science highlight, key goal in next 10 years.
  - A few projects of particular interest.

- Summary

Difficulties

- Science is very broad (but largely covered by earlier speakers – and assume this).
- Techniques cover very wide variety.
- Great many projects:

  6 areas x >5 projects = >30 total projects
- Pointless to try to cover all efforts.
- Not all projects well defined yet
  - – avoid comparisons and cost.
  - – give a rough estimate on timescale.

Personal, selective snapshot – *apologies, etc.*

"Top Hits" since LP 2003

1. Existence of Dark Energy is confirmed by measurements in CMB and X-rays.
   - Initial measurements of CMB polarization made.

2. TeV γ-rays discovered from Galactic Center.
   - Detailed survey of galactic plane – many sources found !

3. Particles E > 10^{20} eV confirmed – what are they?

4. Limits on Dark Matter improved by factor of five to $\sigma < 10^{-42}$ cm^2 .

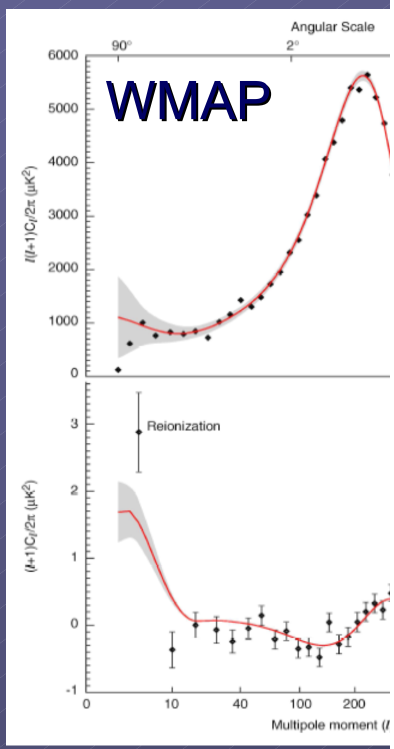
5. Limits on UHE neutrino sources significantly improved by AMANDA.

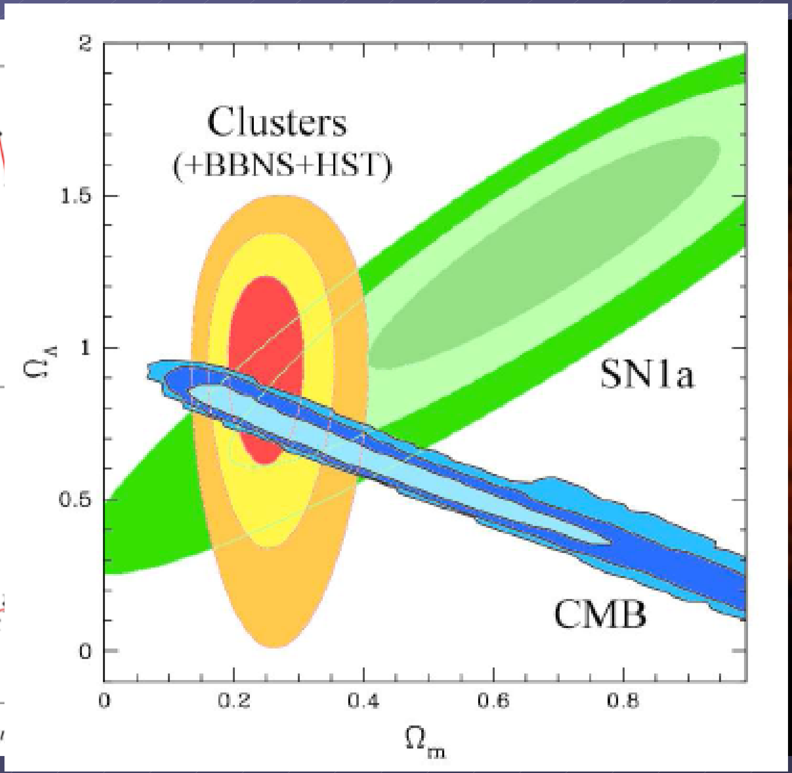
Cosmology

Cosmology

After its discovery in SN Ia, Dark Energy is confirmed by measurements in:

CMB (WMAP) & X-rays (Chandra) & O/IR (SDSS) …





But we don’t have any idea what Dark Energy is !

Cosmology

Physics Goal:

- **Pin down equation of state of universe (ω, ω').**

Accurate determination of expansion history.
Concentrate on O/IR telescopes:

1. Supernova searches.
2. Weak lensing surveys.
3. (Also SN II, SZ, cluster, and other techniques).

Physics Goal:

- **Detect evidence for tensor perturbations from Inflation.**

Detailed study of polarization of CMB.

Current SN and WL Projects

Many SN Ia and Lensing Projects underway.
An <u>incomplete</u> list:

Project	Possible complete Date	Weak-Lensing (sq-deg)	Number of SN Ia	Redshift range
Deep Lens Survey	2005	28		
CFHT WL Legacy	2006	170		
* CFHT SN Legacy	2008		800	$0.2 < z < 0.9$
ESSENCE	2008		200	$0.15 < z < 0.75$
Nearby SN Factory	2008 ?		300	$0.1 < z < 0.3$
CfA SN Program	2008		200	$z \sim 0$
Carnigie SN Prog.	2010		> 100	$z < 0.07$
Suprime on Subaru	ongoing			

* See Poster #212 by N. Regnault.

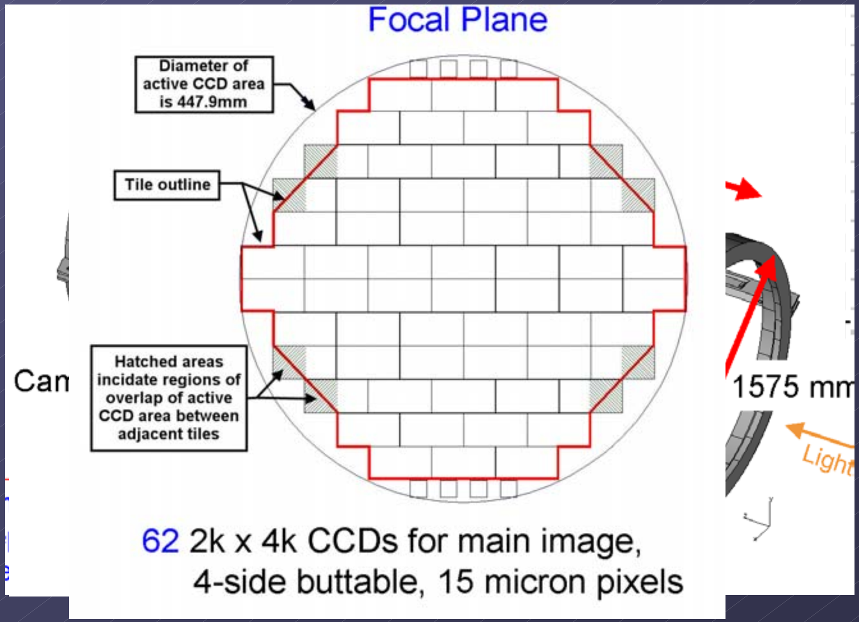
L. Knox

Weak Lensing

Dark Energy Survey (2006 ?):

5000 sq-deg over 5 years.

Blanco 4m (Cerro Tololo)

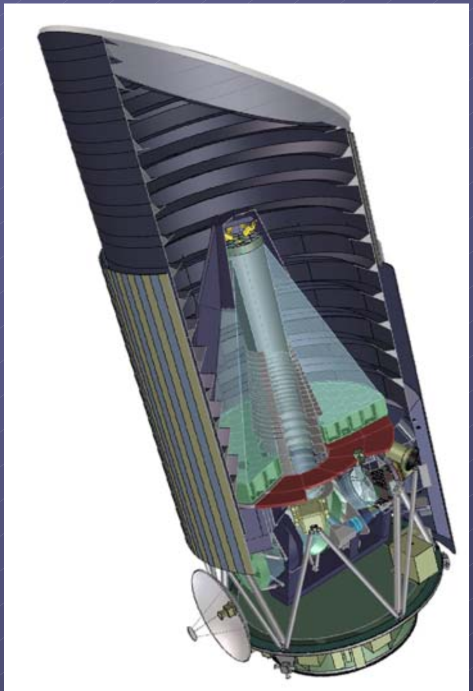


Camera: 2.2^{o} FOV
64 CCD's, DAQ

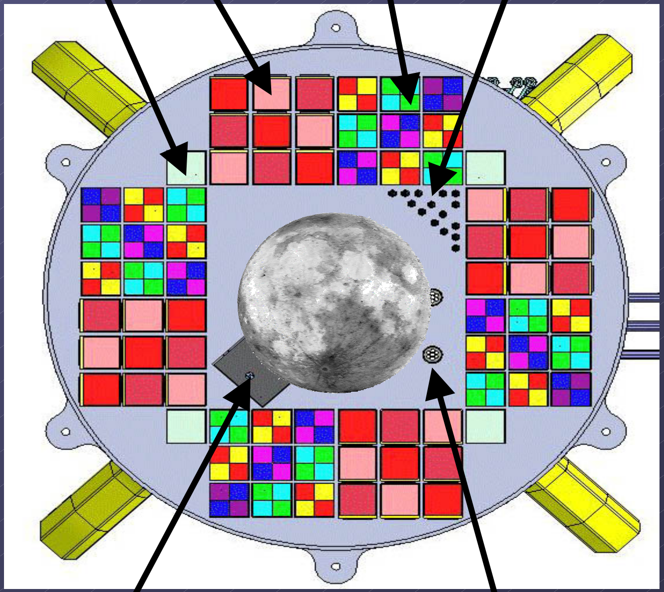
SN Ia

SNAP: (2012 ?)

Possible mission for JDEM.
Measure 2,000 SN Ia to z=1.7



2m space Telescope



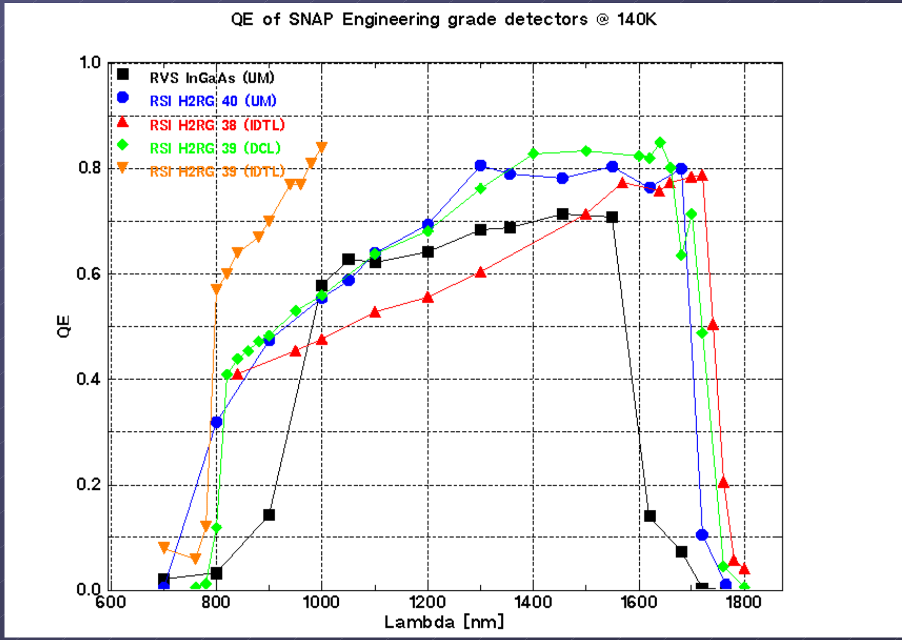
Camera:
0.7 sq-deg, Visible -> NIR

NIR Detectors

New generation of NIR detectors
→ Crucial for getting to z=1.7.

G. Tarle

2k x 2k, 1.7μm HgCdTe



Quantum efficiency

Future SN and WL Projects

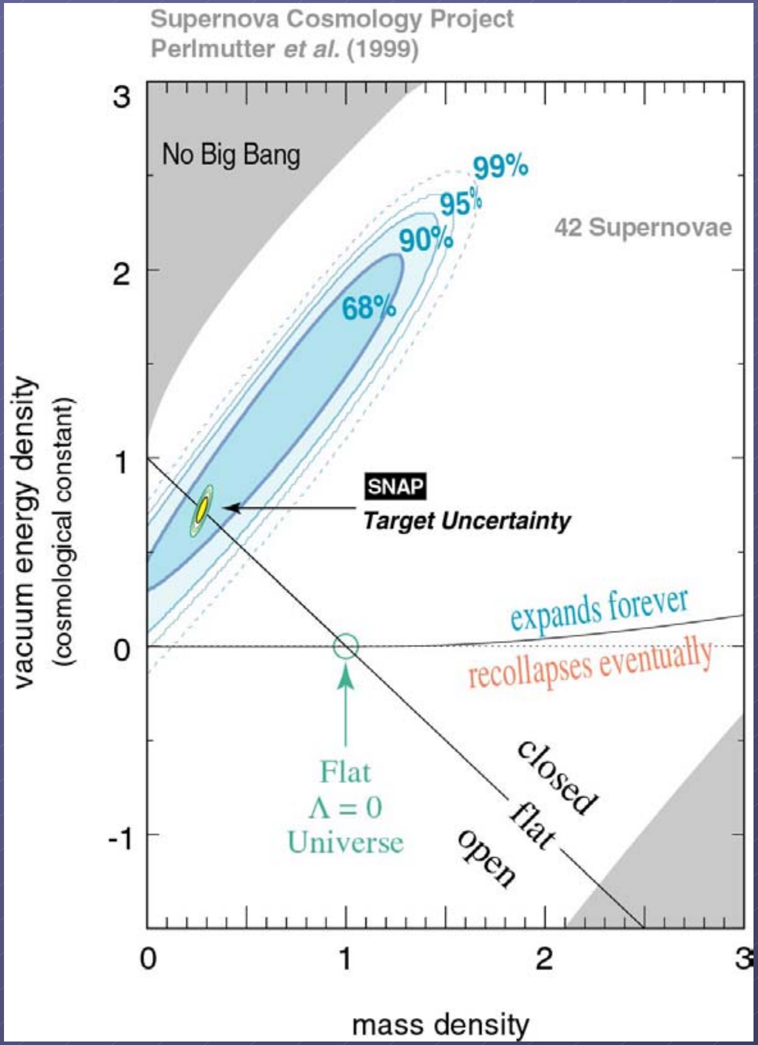
An incomplete list of proposed projects:

L. Knox

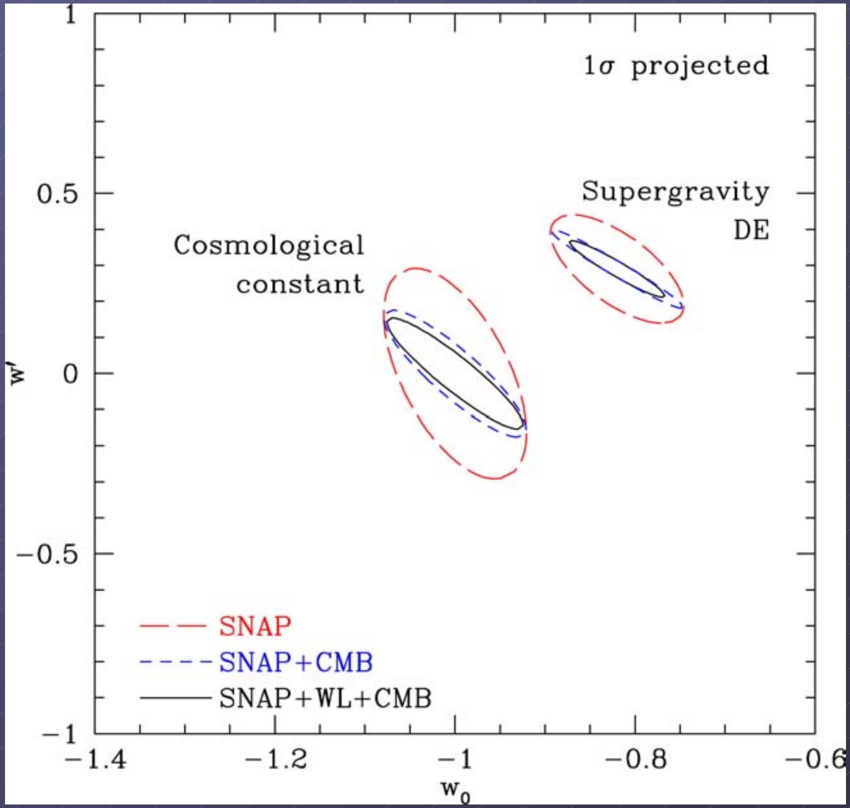
Project	Possible Start	W. Lens. (sq-deg)	Number of SN Ia	Redshift range
KIDS (OmegaCam)	2006 ?	1000		z < 1.2
PANS (HST)	2006		60	z > 1.0
Dark Energy Survey	2009	5000	1900*	0.3 < z < 0.75
ALPACA	2010	1000	50000*	z< 0.80
Pan-Starrs	2010	30000		z < 1.0
LSST	2012	20000	60000*	z < 0.75
Destiny	2012+		>2000	0.5 < z < 1.7
JEDI	2012+	10000	~2000	z < 2.0
SNAP	2012+	1000	2300	0.1 < z < 1.7

* No spectroscopy

General Sensitivity



Constraints on Ω_Λ and Ω_m.

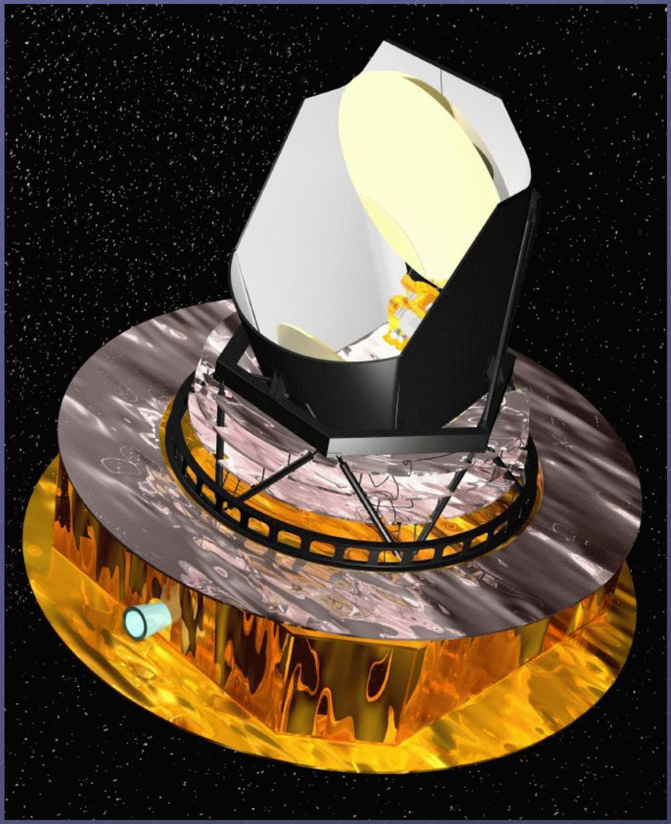


Constraints on Eq. of state

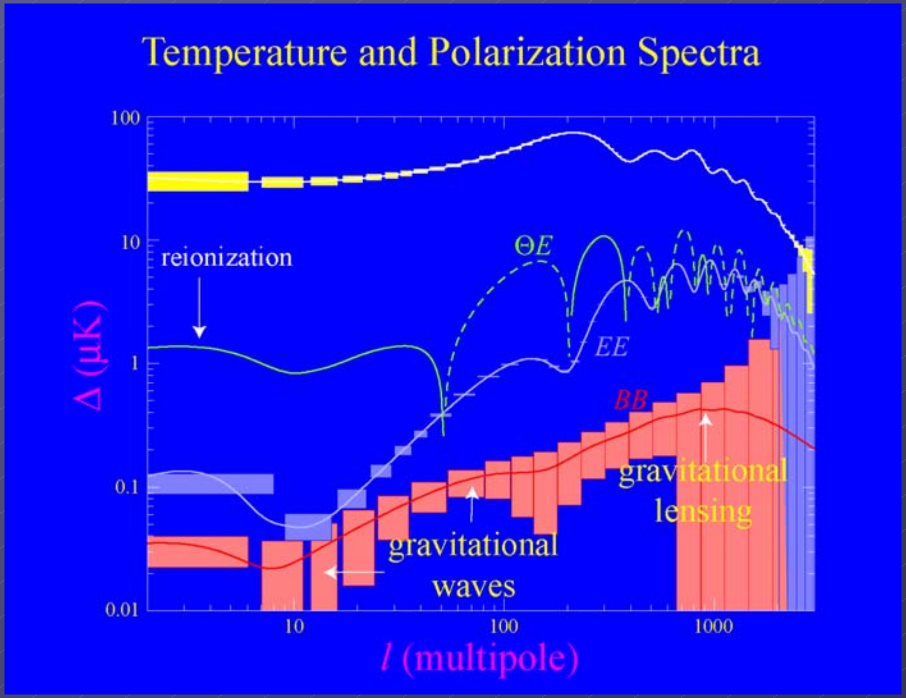
Planck CMB Mission

Planck: (2007)

All-sky survey at 5′



W. Hu



Planck:
Measure E-mode polarization well.
Break degeneracies in parameters.

Not a good measurement of B-modes.

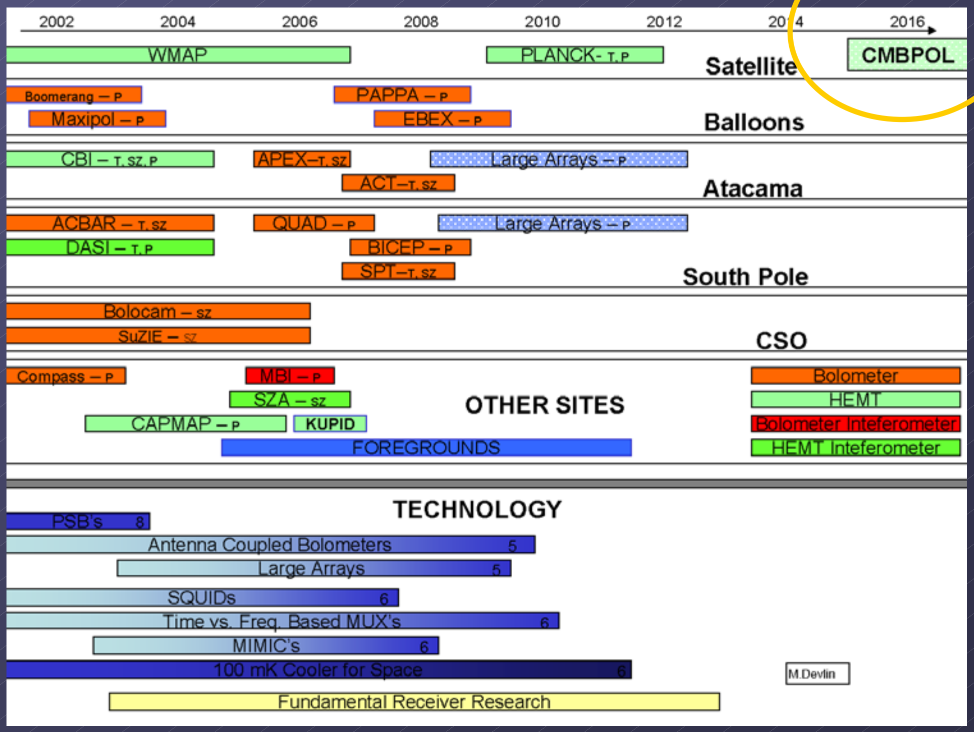
CMB Polarization Expts.

Parameters for a long-term Experiment:

- ~1000 receivers.
- Receivers at photon statistics limit.
- Wide frequency covereage ~ 30-250 GHz.
- On the ground, on balloons, in space…

NASA
Inflation Probe
(2015 ?)

Many experiments being discussed.

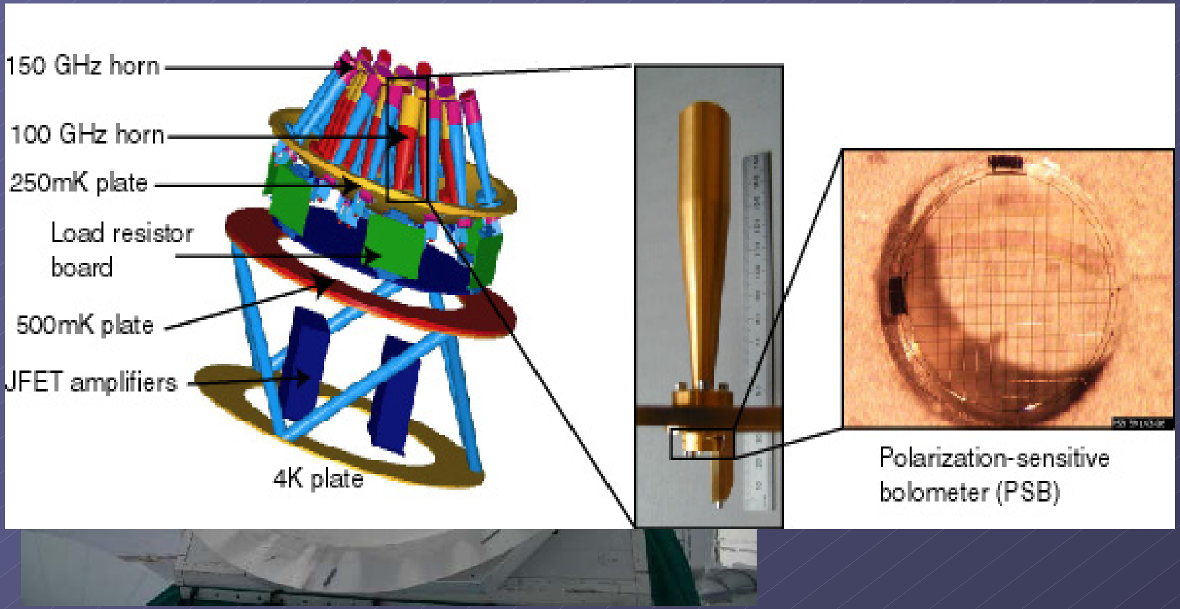


CMB Task Force (U.S.)
R. Weiss (chair) Preliminary!

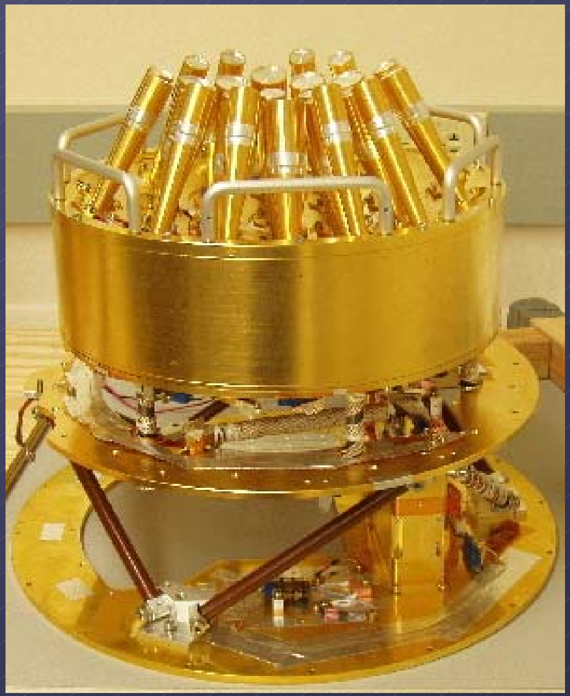
A Near-Term CMB Project

<u>One</u> example:

QUaD Experiment (2005).
6′ (100Ghz), 4′ (150 GHz).
300 sq-deg in two years.



2.6m primary & QUaD receiver
(South Pole)



Focal plane
Feedhorns, PSB’s

Dark Matter

Dark Matter

Physics Goal:

- Discover a new particle, possibly at Weak scale.

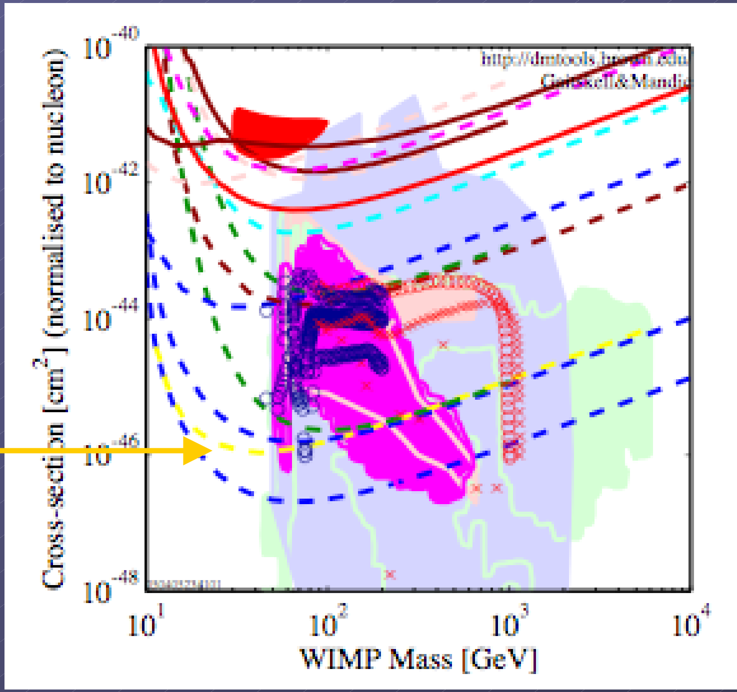
Physics Goal:

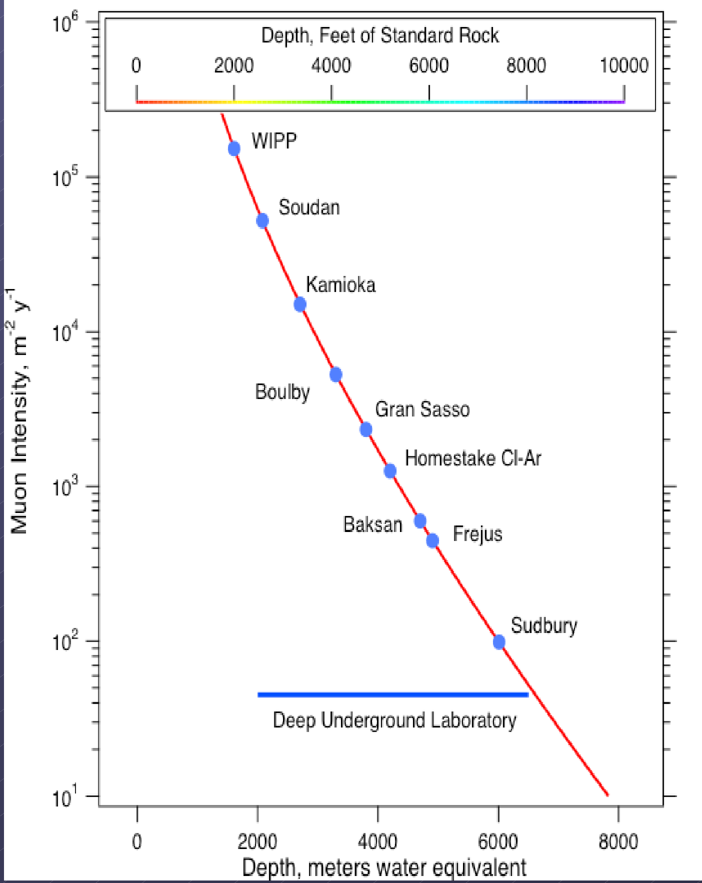
- Discover a new particle, possibly at Weak scale.

To get to cross sections $\sigma < 10^{-46}$ or lower:

- Much bigger (~ 1 Ton) detectors.
- Cleaner detector fabrication, operation.
- Reduced bkgnd. and deep site.

1 T Detector (2013 ?)





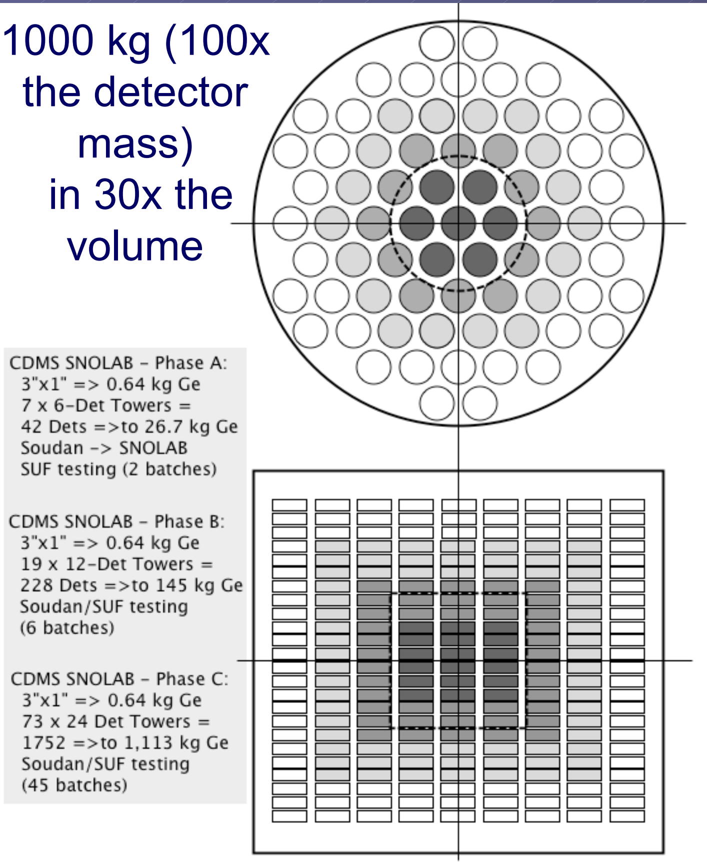
R. Gaitskell

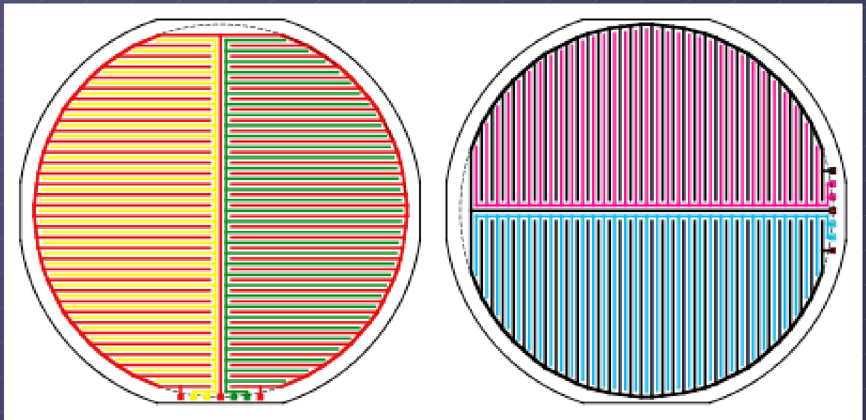
Future Dark Matter Projects

One example:

Super CDMS (2013?)

Phased approach: (25, 150, 1000) kg of Ge.





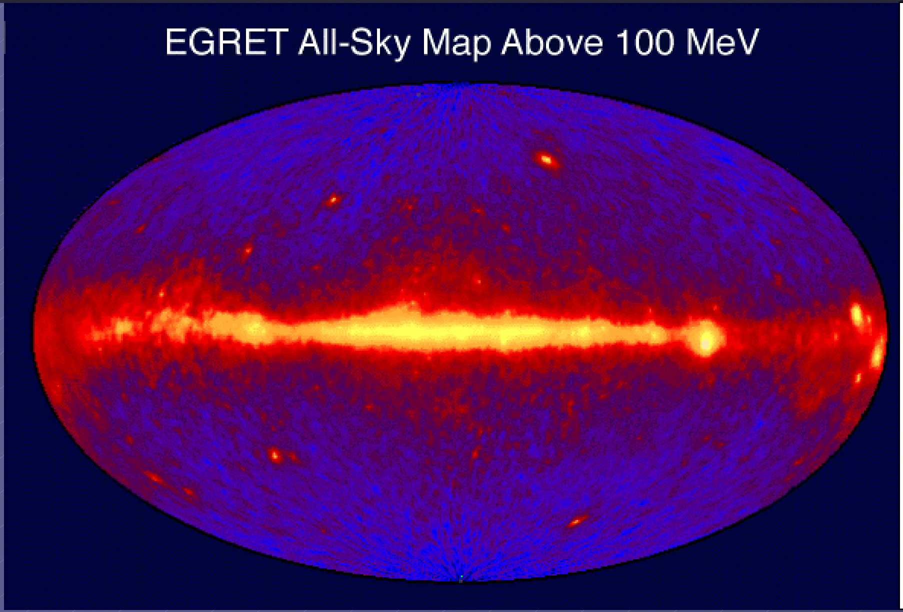
Double-sided interleaved phonon sensors with differential bulk vs. surface charge response.

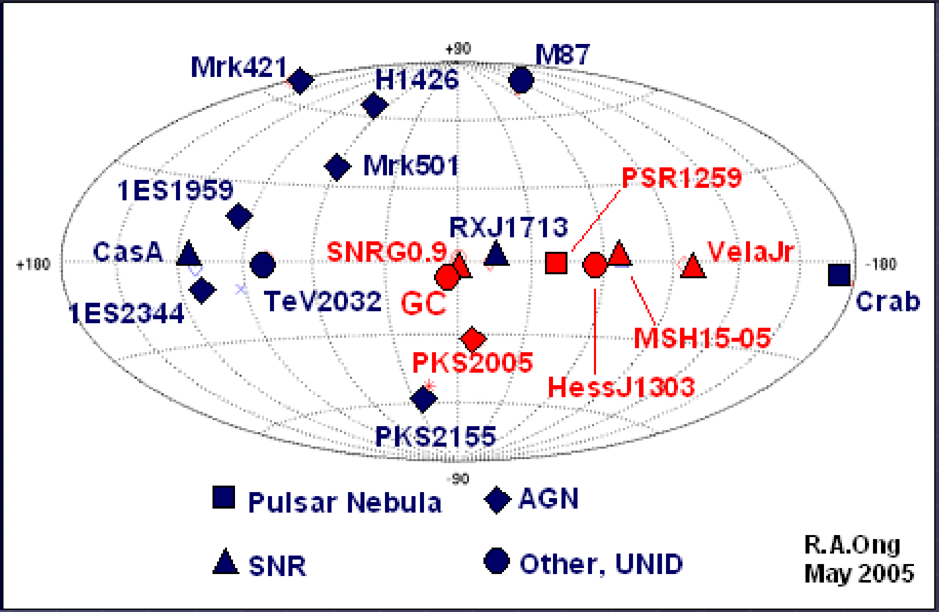
Other approaches:
Genius, DRIFT, etc.

VHE Particles

γ-ray GeV

γ ray TeV



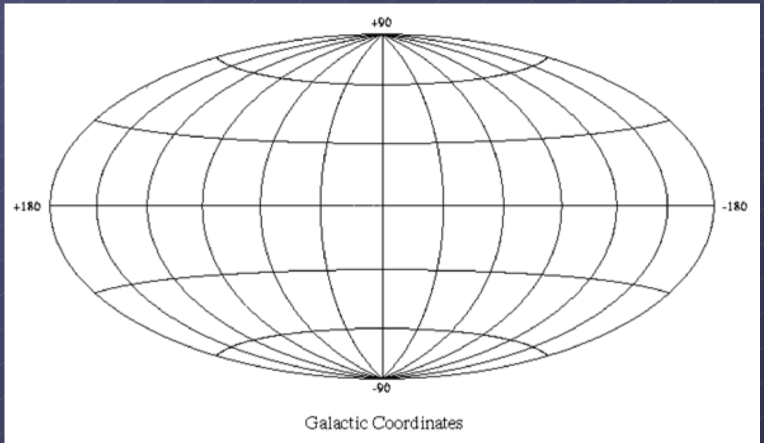


300 sources: mostly AGN, UNID

19 sources: AGN, SNR's, Pulsars, GC, M87, and UNID

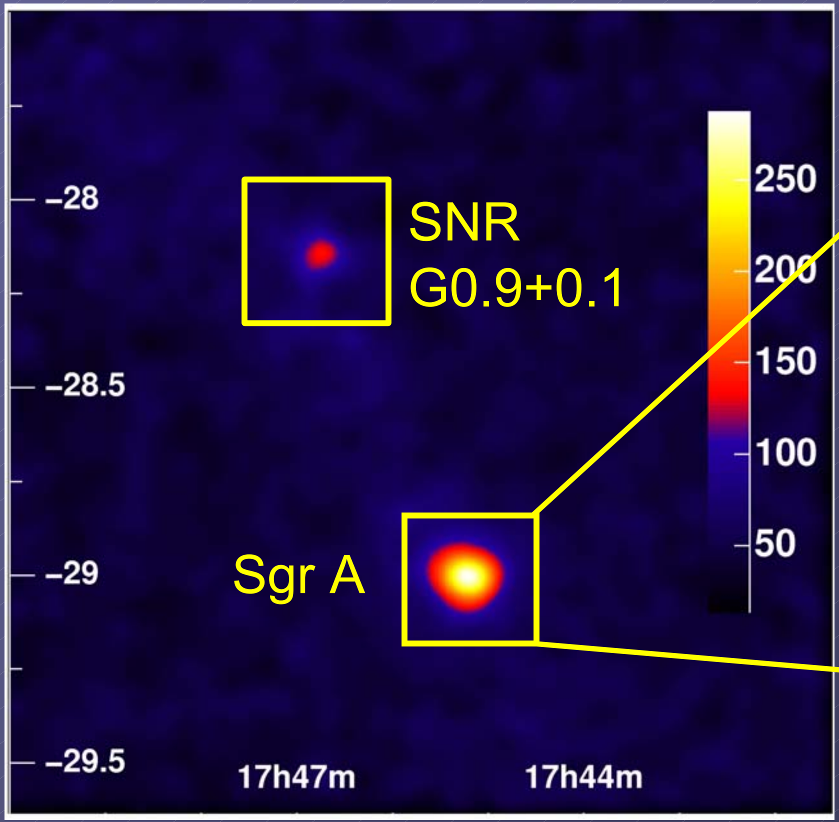
VHE ν's

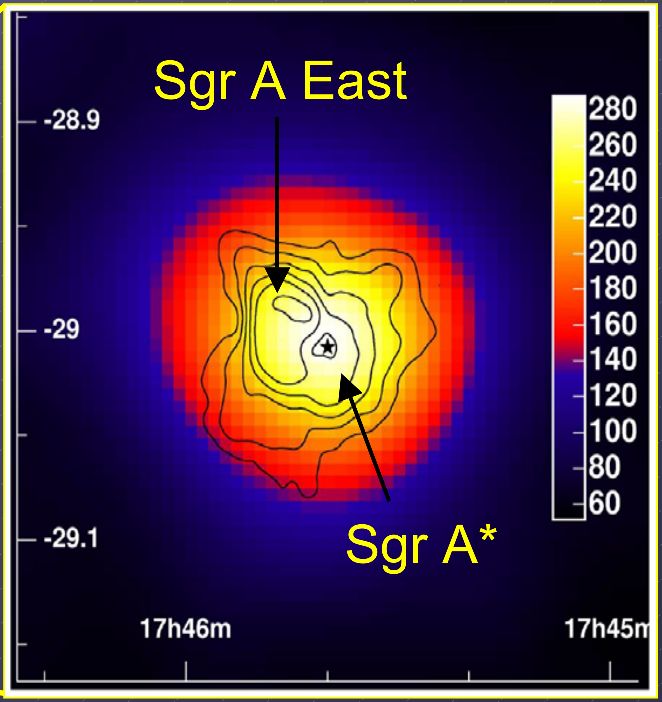
No sources yet.



TeV γ-rays

TeV γ-rays detected from Galactic Center.





HESS

Strong source; power-law spectrum
Origin not understood !

VHE γ-rays

VHE γ-rays

Physics Goal:

- Survey GeV/TeV sky with great sensitivity – discover new sources and study very distant ones.

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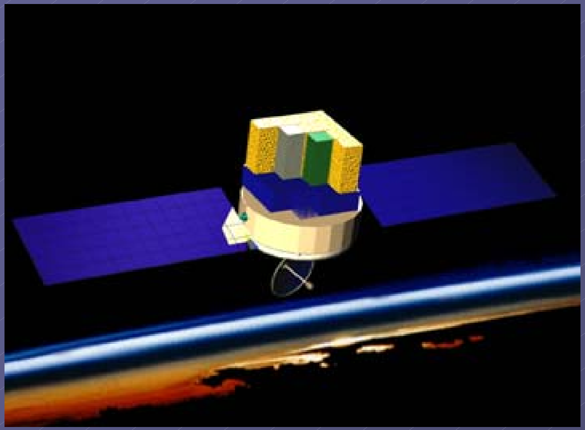
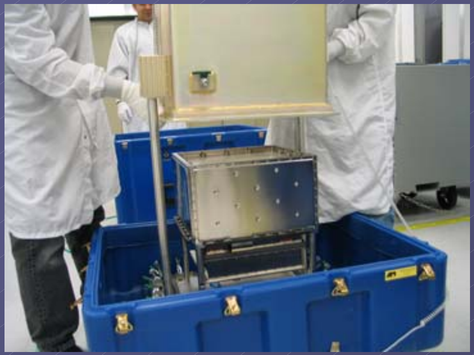
- Survey GeV/TeV sky with great sensitivity – discover new sources and study very distant ones.

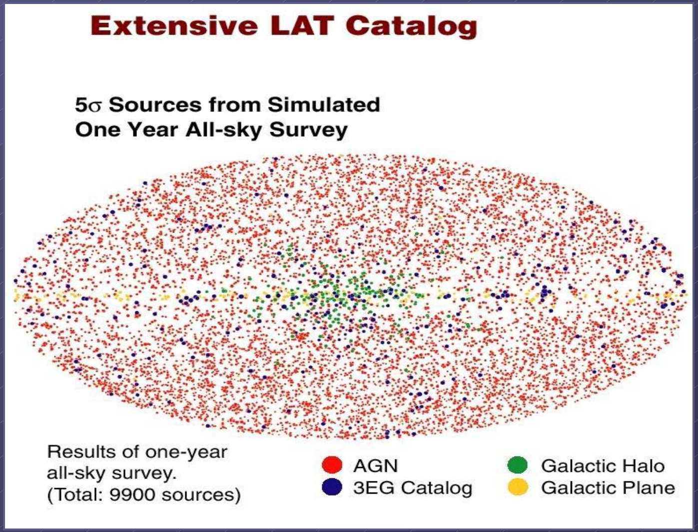
1. GLAST (space-based, 2007)



LAT:
Silicon Tracker
CsI Calorimeter
1.8m x 1.8m



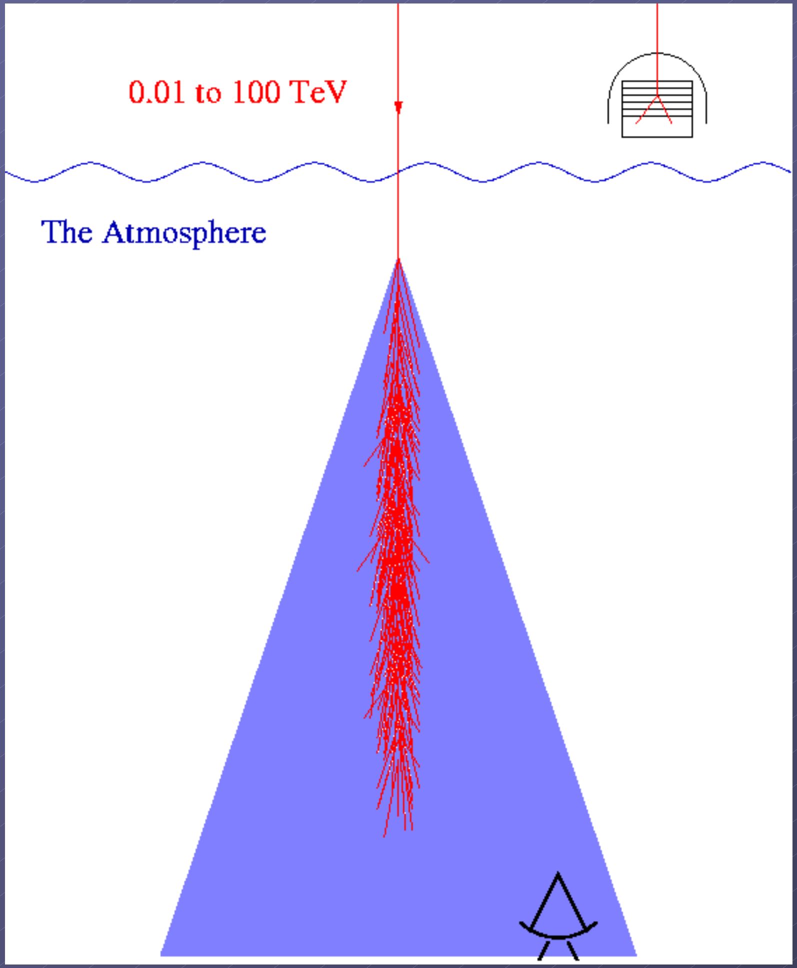
Construction (6/05)



- ~ 5000 sources expected.
- Redshift range z ~ 5.
- Study of DM in galaxy.
- Probe IR absorption.

γ-ray Projects

2. Atm. Cherenkov Telescopes

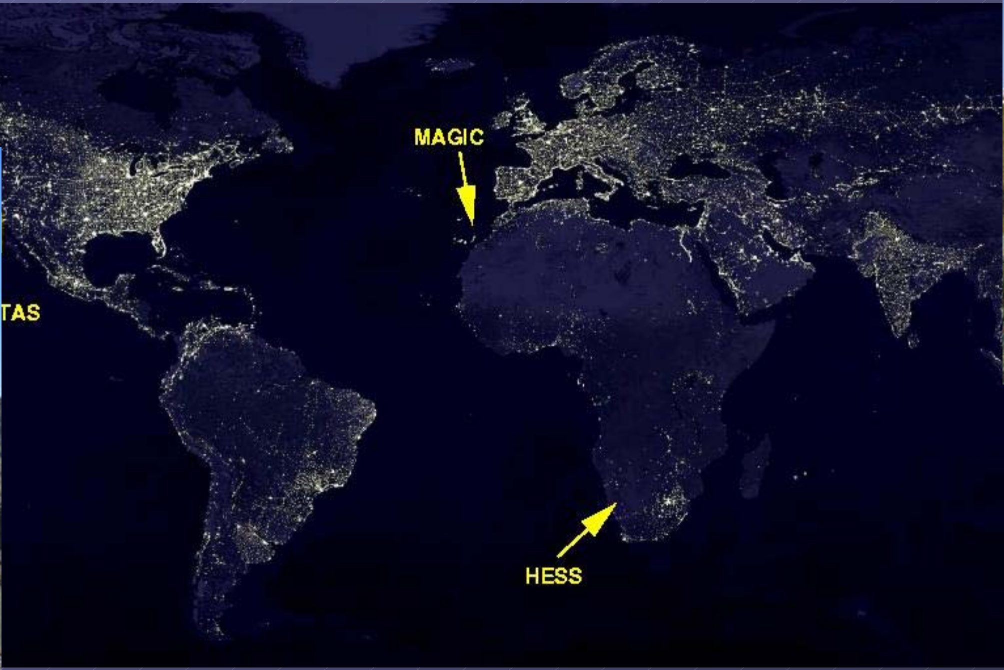


Present Cherenkov Expts:

- E ~ 100 GeV
- Ang. Resolution ~ 4′
- Back. Rej. > 5,000.
- Detect Crab at 50 γ/min. (20 sec for 5σ).

Cherenkov Telescopes

MAGIC:
1 x 17m telescopes
2 x 17m in 2008.



VERITAS:
2 x 12m telescopes
4 x12m in 2006.

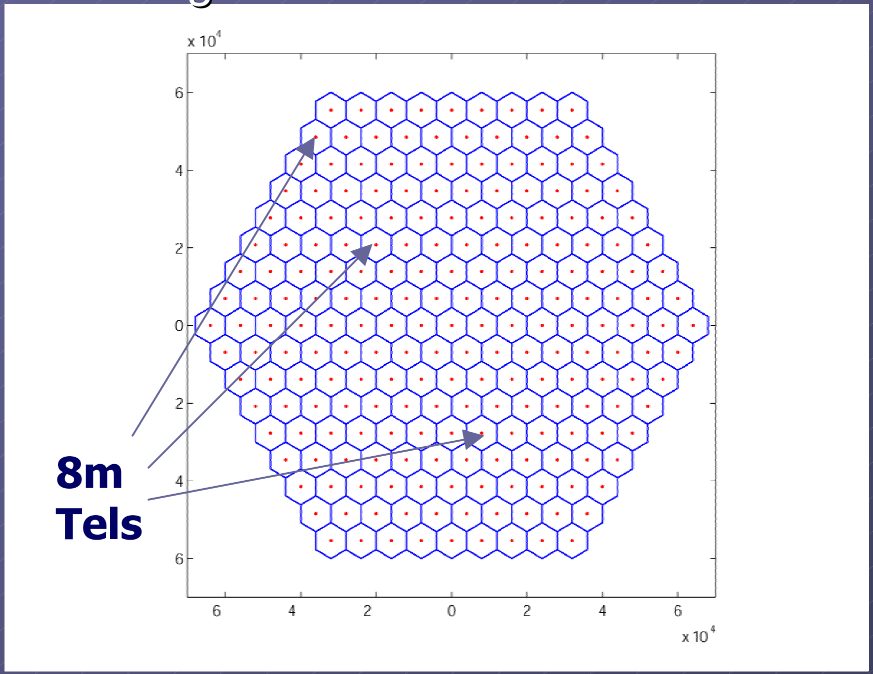
HESS: 4 x12m telescopes + 28m (2008)

CANGAROO:
4 x 10m telescopes

Future γ-ray Telescopes

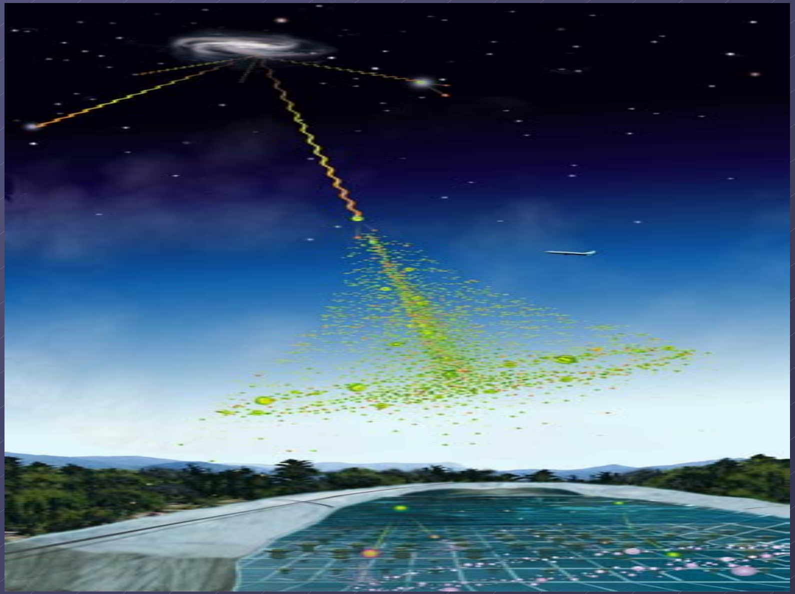
A. Low energy, wide FOV, with huge collection area:

- 1 km^2 of 8m telescopes.
- FOV = 15^o.
- High altitude site.



HE-ASTRO (V. Vassiliev)

HAWC



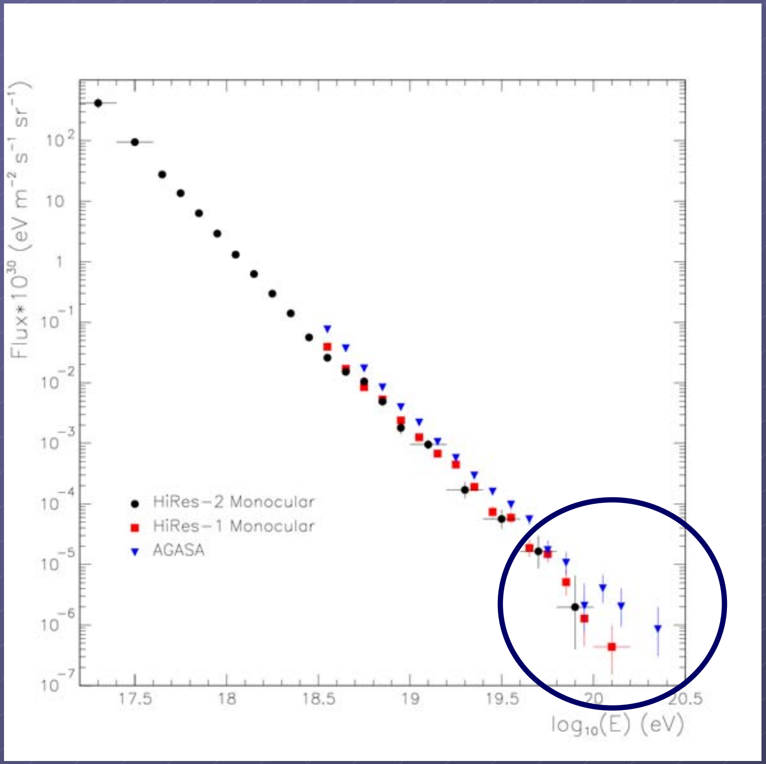
B. Very wide FOV survey:

- 300m x 300m pond.
- FOV = 2 SR.
- Very high altitude site (4000 m).

UHE Cosmic Rays

UHE Cosmic Rays

Following AGASA results, two other experiments confirm existence of 10^{20} eV particles.



AGASA, HiRes (D. Bergman)

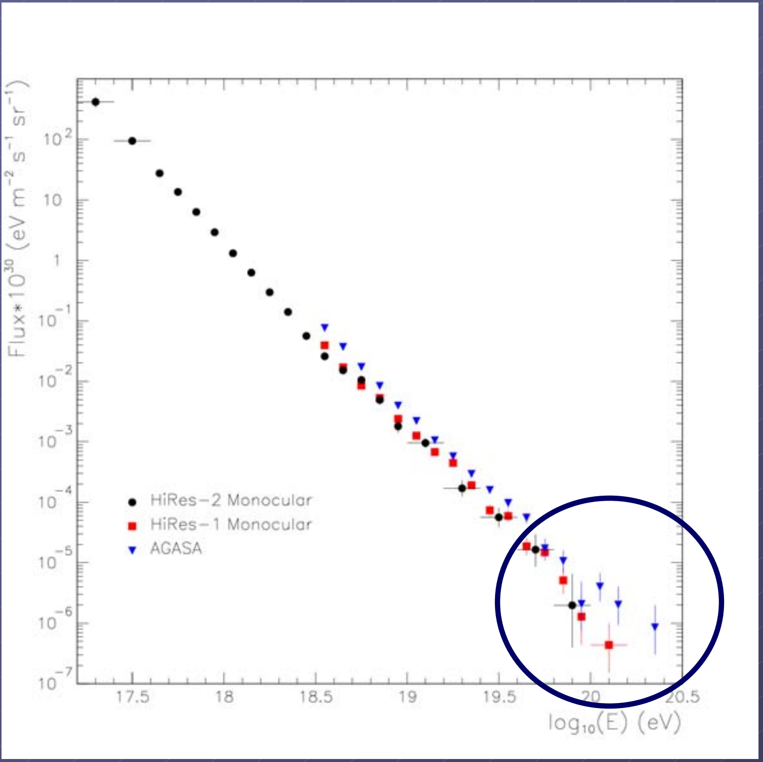
Auger (preliminary)

We do not know how to produce these particles.

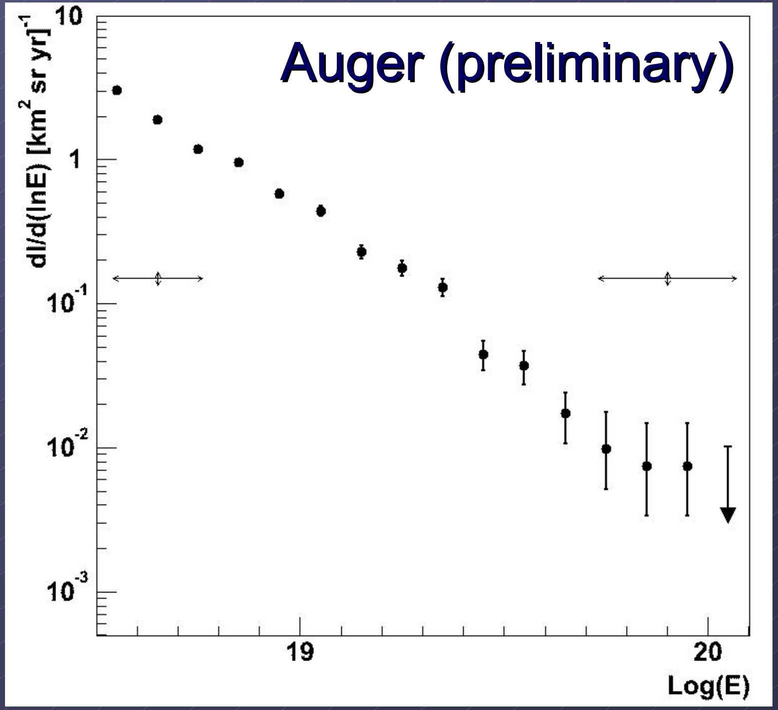
Physics Goal:

- Determine the origin of the highest energy CR's.

Following AGASA results, two other experiments confirm existence of 10^{20} eV particles.



AGASA, HiRes (D. Bergman)



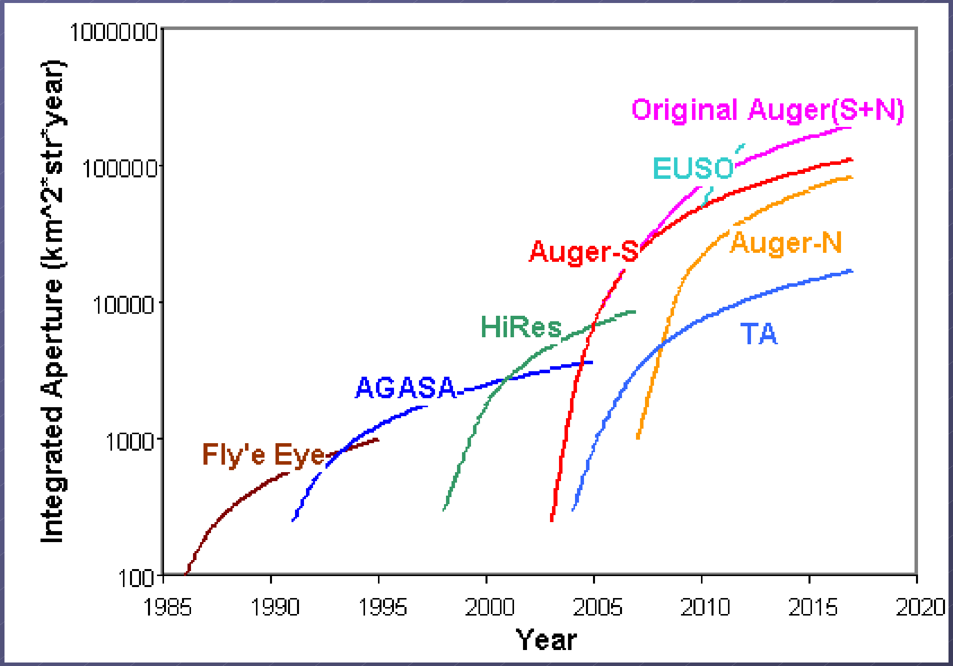
We do not know how to produce these particles.

Physics Goal:

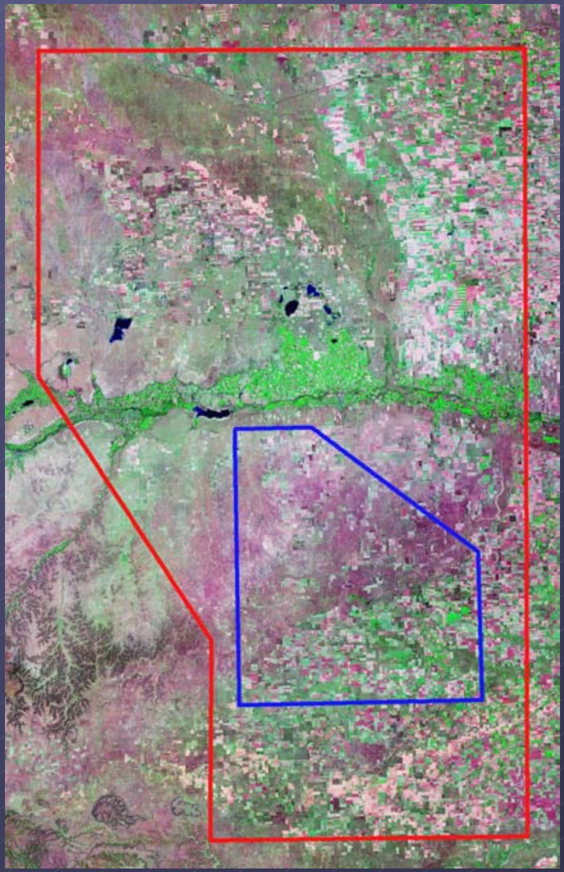
- Determine the origin of the highest energy CR's.

To really pin down models:

- Precise spectra → large aperture.
- Trace origin → full sky coverage.
- Good composition information.



UHECR aperture vs time.



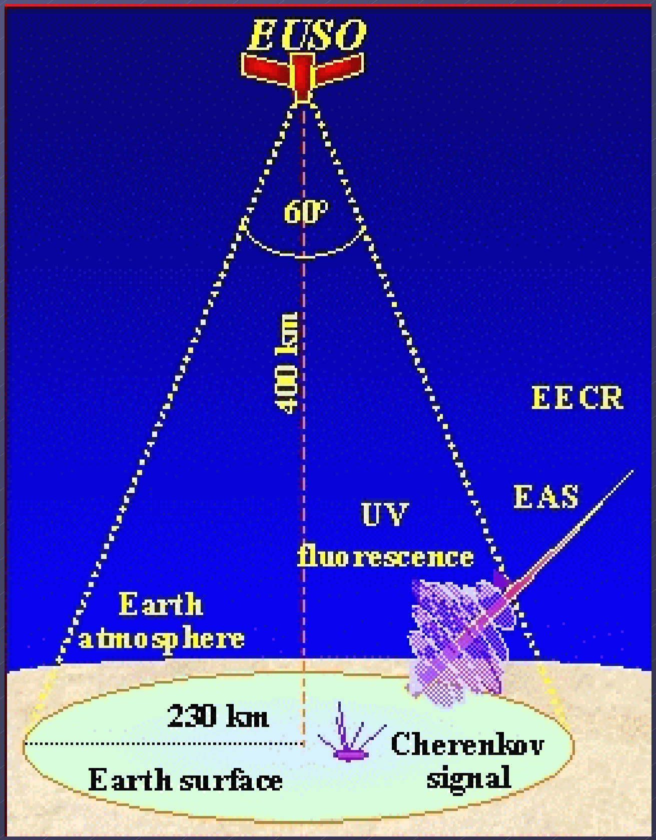
1. AUGER North

Eastern Colorado, USA
Up to 15,000 km^2 !

UHECR Projects

2. Extreme Universe SpaceObservatory (EUSO) Phase A study for ESA.

- N_2 Fluoresence technique.
- 60^o FOV, 0.25 Mpixels.
- Aperture of 5 x 10^5 km^2 sr.
- On Space Station.



UHE Neutrinos

UHE Neutrinos

Physics Goal:

- Detect neutrinos from GZK and point sources with good significance. Measure UHE ν cross-section.

Physics Goal:

- Detect neutrinos from GZK and point sources with good significance. Measure UHE ν cross-section.

To have sufficient sensitivity:

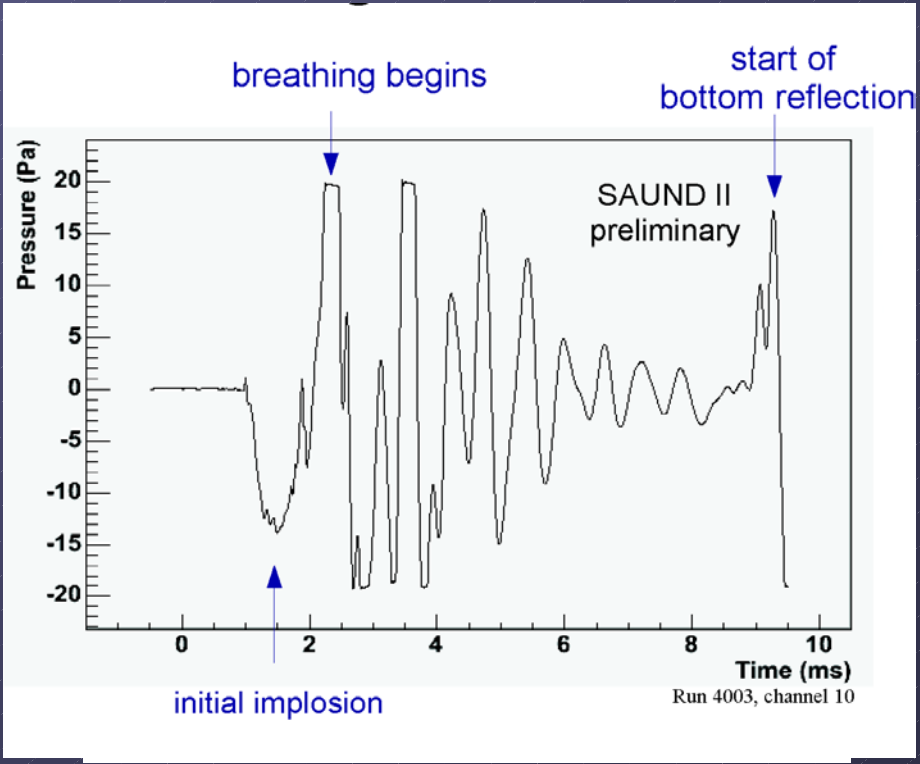
- Huge collection area: ~ 500 km^2 sr.
- Medium ~ O(1 km) attenuation.
- Radio or acoustic possibilities.

1. Acoustic Detection

Shower heating generates accoustic pressure.

SAUND Prototype

- 60 hydrophones.
- ~ 1000 km2 area !
- Initial studies in progress.



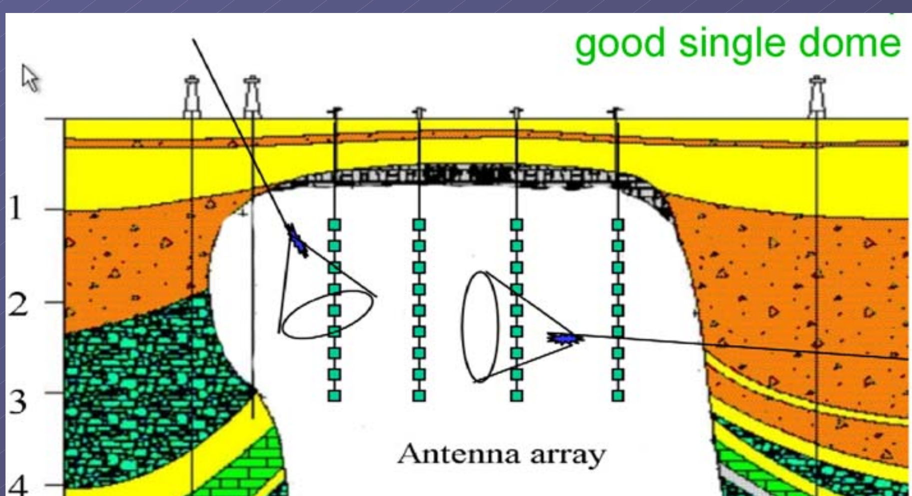
SAUND II Array

UHE ν Projects

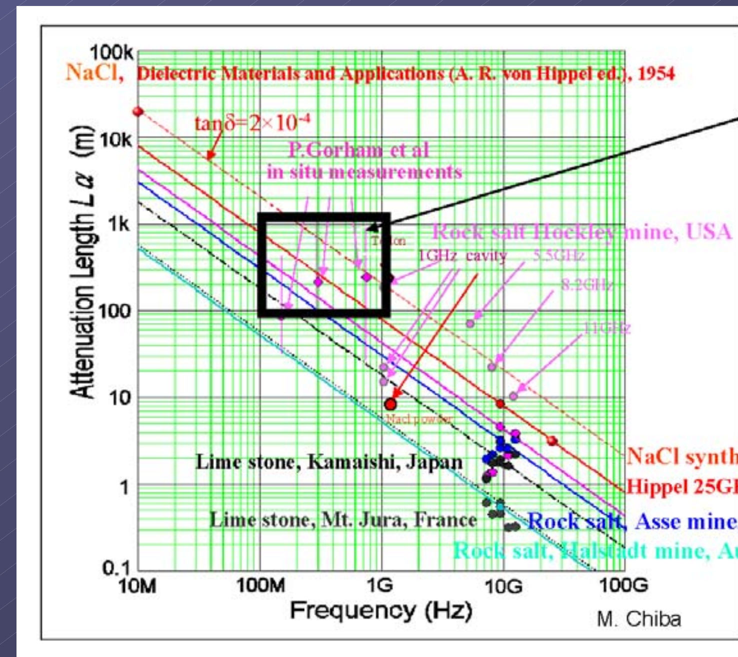
2. SALSA (2012?)

Large SALT formation (dome) – exist.
Antennas spaced by λ_o
Denser than ice by ~ 2.5.

P. Gorham



SALSA Concept



Attenuation lengths (initial measurements)

Also measuring acoustic properties.

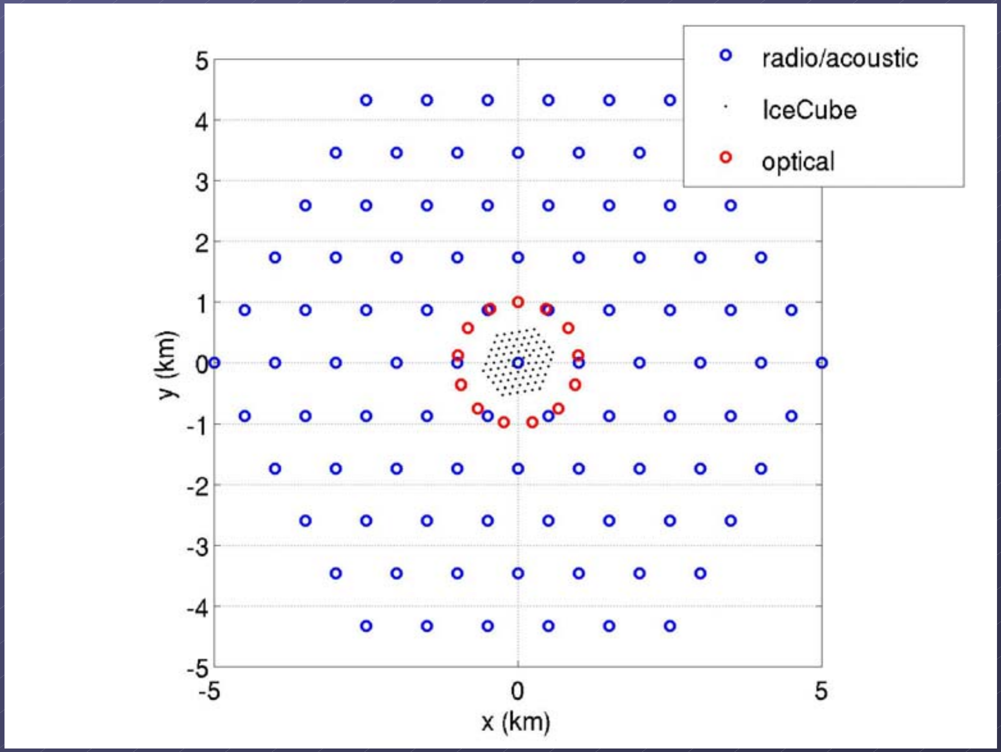
UHE ν Projects

3. IceCube Extension (2015 ?)

Hybrid Array:
optical,
radio & acoustic detectors.

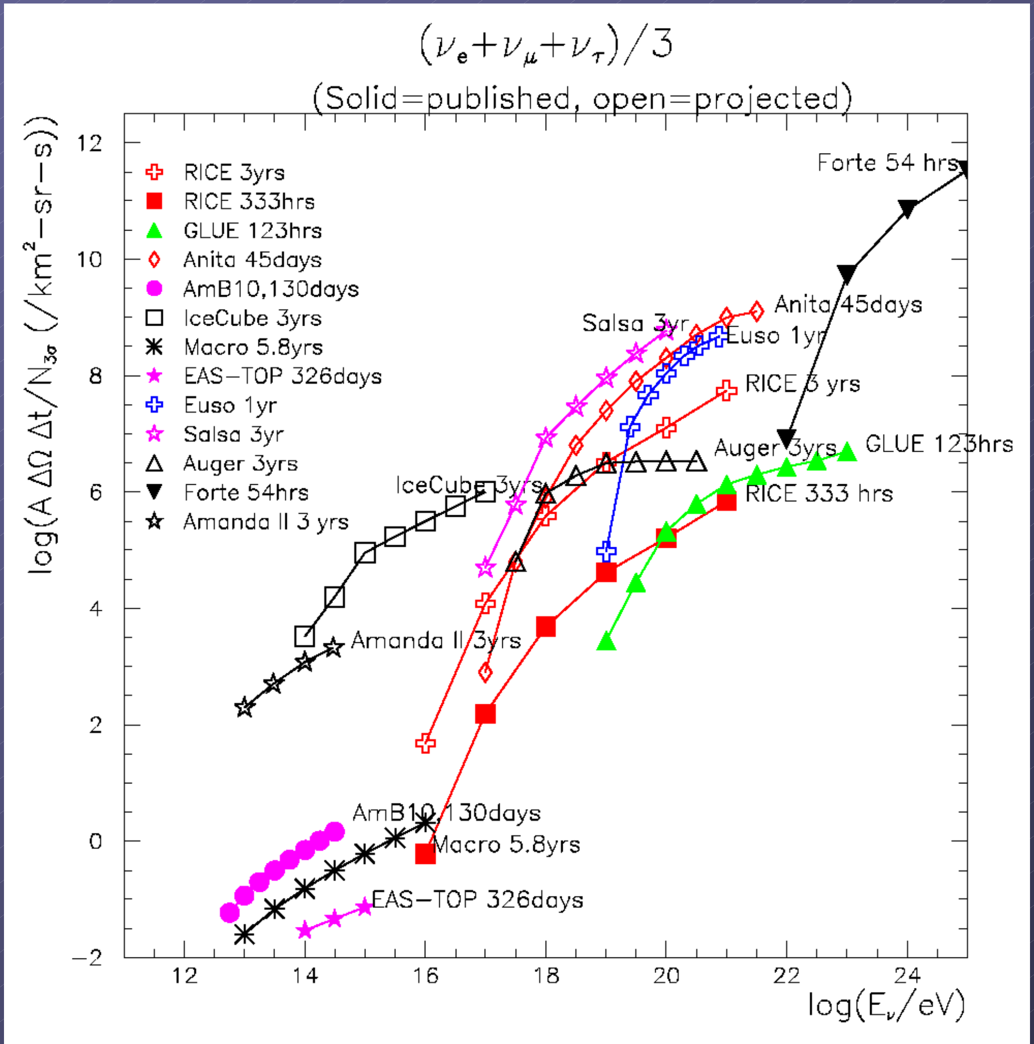
~ 100 strings on 1 km spacing.

V > 100 km^3 (10^{19} eV).



J. Vandenbroucke

UHE ν Aperture



D. Saltzberg

Neutrino “discovery aperture” vs. Energy.

Future: General Trends

1. Myriad of new Experiments and Techniques:

   Growing interest. ("Beam is always on")

2. Projects getting more expensive ($$ and people):

3. Funding realities:

   Total cost, scaling up, programmatic considerations.

Not all projects will be built, some will be delayed.

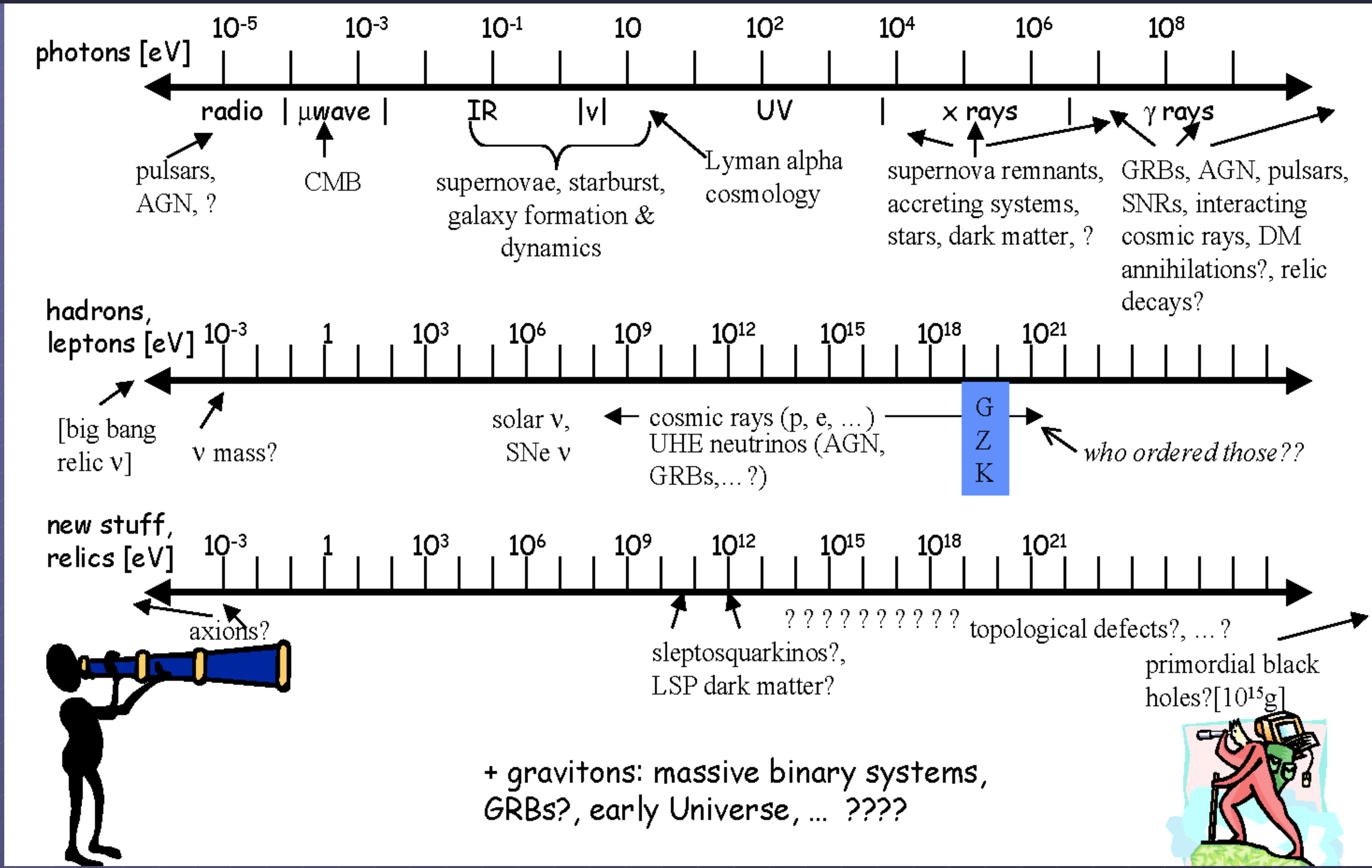
Summary

- Particle astro and cosmology continue to be very exciting scientifically.
- Great variety of techniques makes these very interesting areas to work in (& particle physicists have already made big impact).
- Many ongoing efforts and probably too many things being developed or proposed.
- New projects share a common thread:

  Scaling up to greater sensitivity or aperture.

  But, the technological choices are not yet obvious.

Messengers … Recap



S. Ritz

Thanks (!) to many ..

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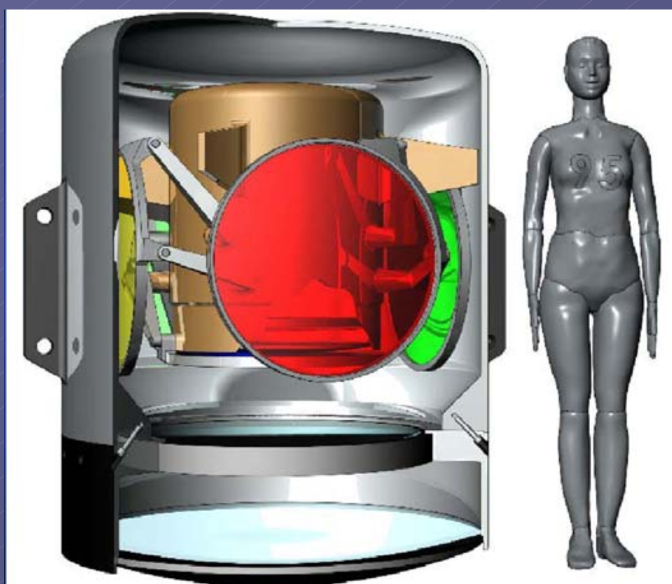
Rai Weiss, Stefan Westerhoff, & Bruce Winstein

END

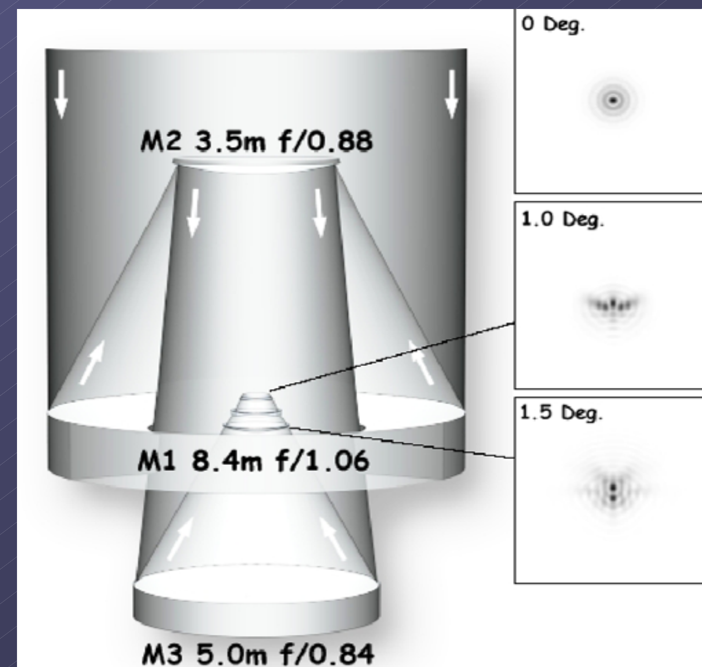
Extra Material

Projects in Weak Lensing

2. Large Synoptic Survey Telescope (LSST, 2012 ?):



Camera:
8.6 sq-deg = 2.8 GPixels
20 TBytes per night



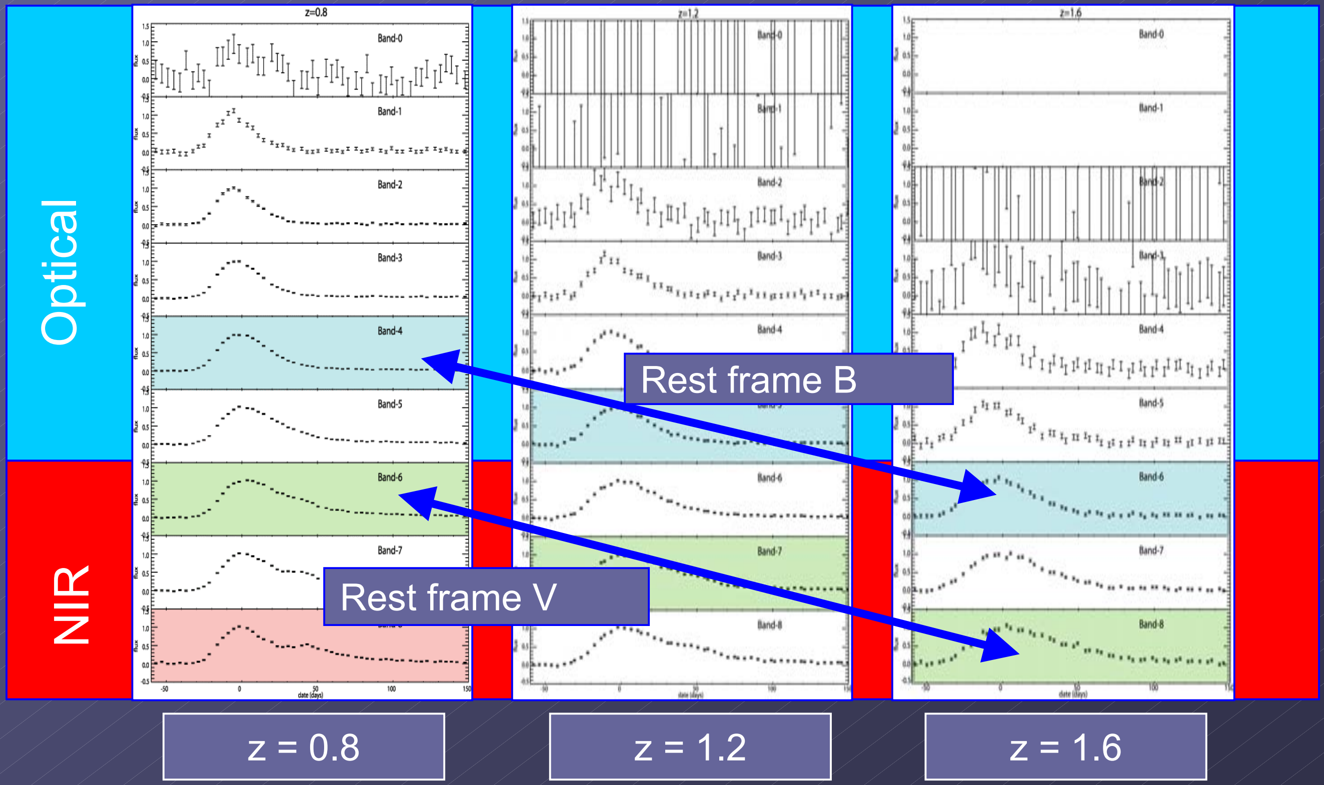
Telescope:
8.4m, tertiary design

High Redshift SN Ia

2. Space telescopes (SN Ia and lensing)

High Redshift SN Ia requires NIR capability:

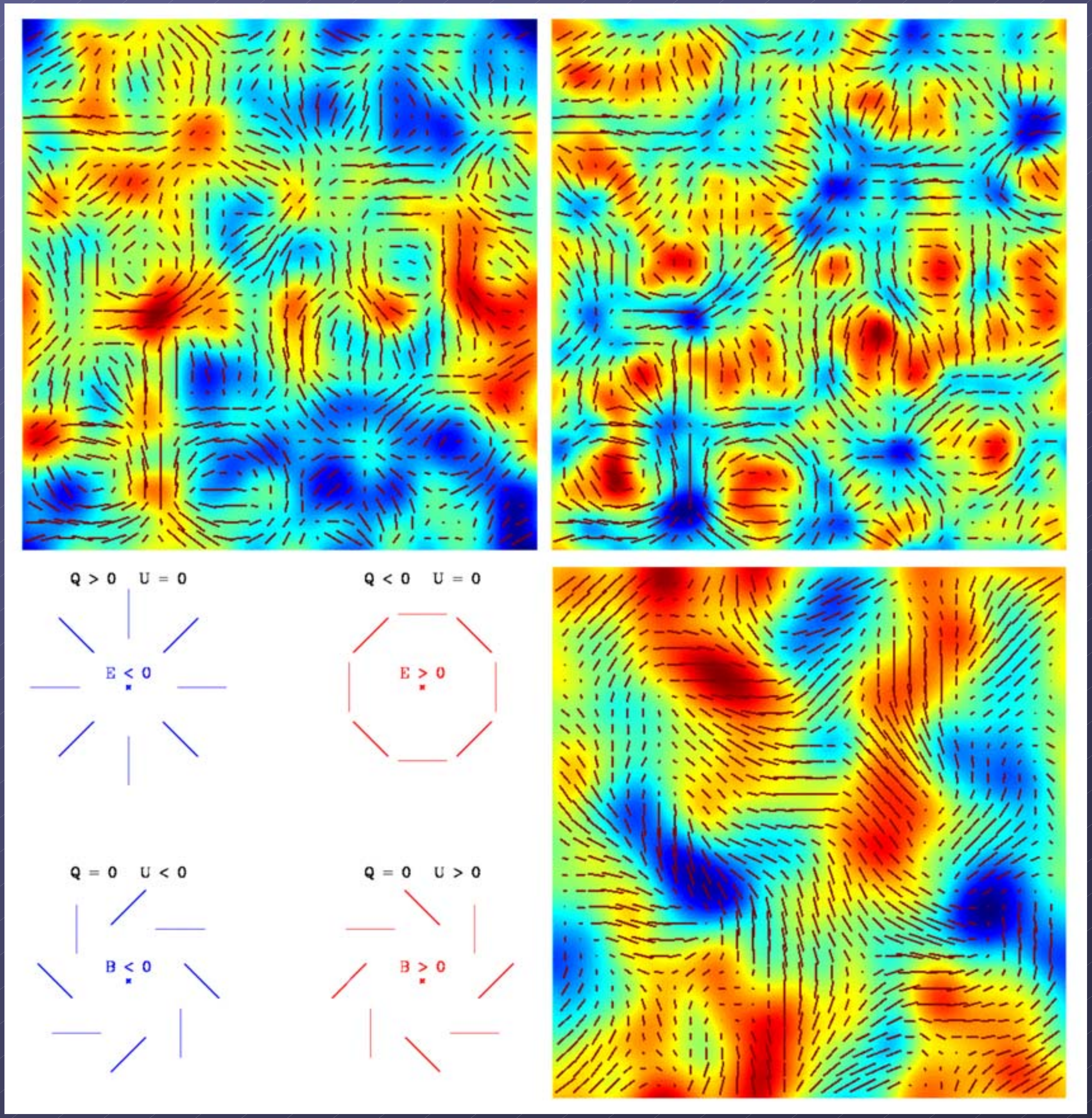
Simulated SNAP observations of high redshift SNe



E & B Mode Polarization

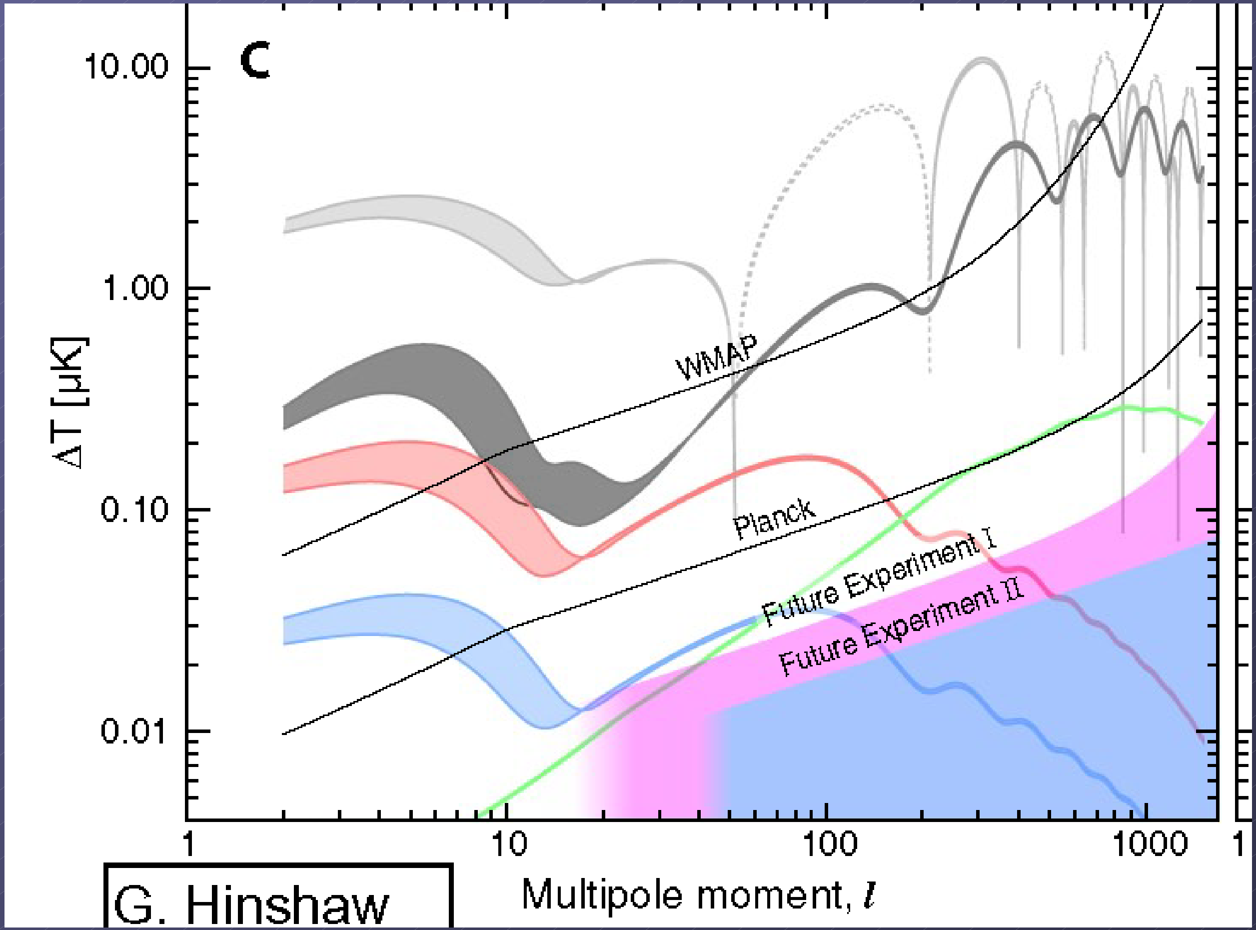
E mode:
  Even parity of Q & U.
  Scaler and tensor pert.

B mode:
  Odd parity of Q & U.
  Tensor pert. and grav. lensing.



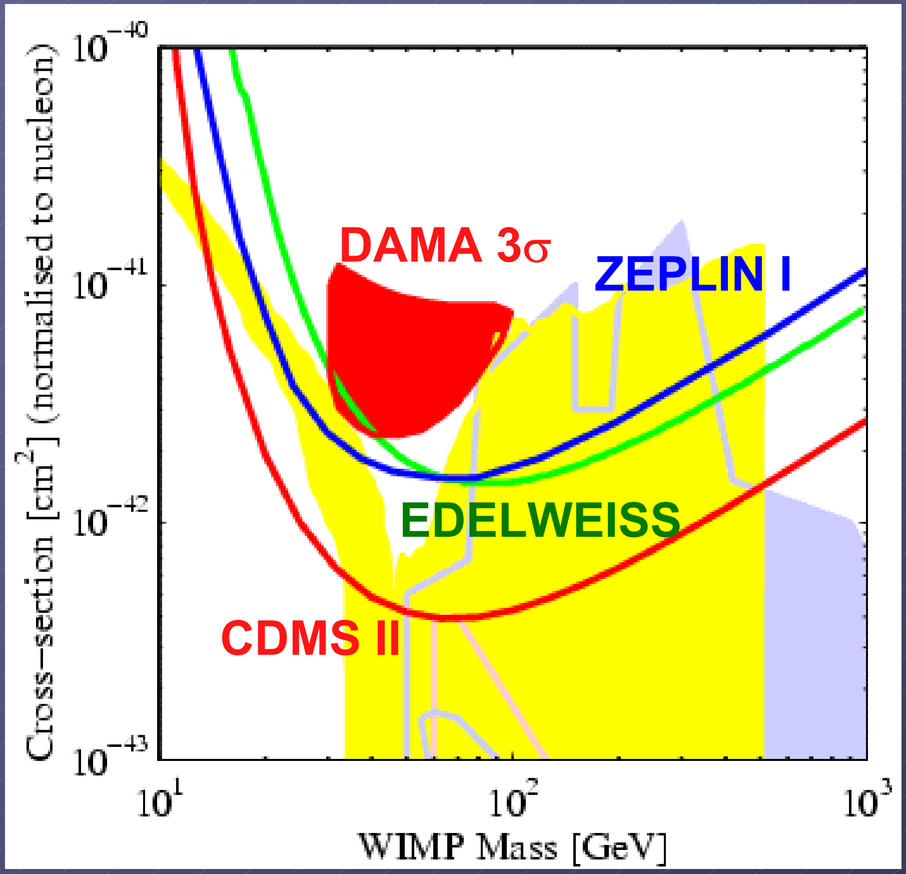
Future CMB Sensitivity

Projected Experimental Sensitivity



Dark Matter

Dark Matter limits substantially improved.



DAMA result not confirmed.

Pushing into interesting parameter space.

L. Baudis

VHE Particles (γ, CR, ν)

P. Gorham

The three messengers:

γ, CR, ν

each contain unique astrophysical information.

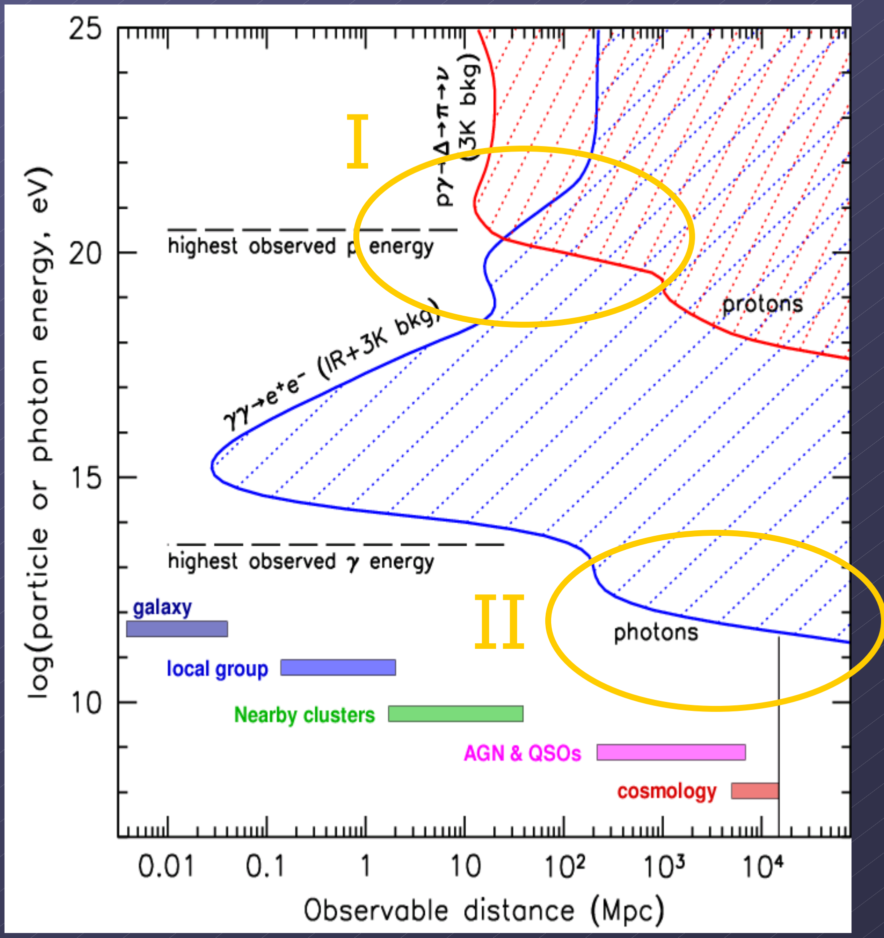
Absorption processes are crucial:

γ-rays (TeV):

$\gamma\gamma \rightarrow e^+ e^-$

CR (10^{20} eV):

$p\gamma \rightarrow \Delta \rightarrow \pi$'s

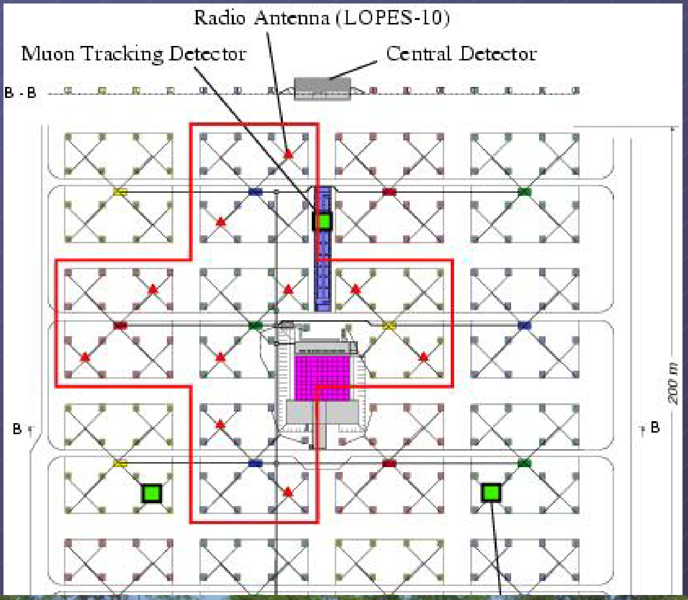


UHECR Projects

3. Radio Detection of CR’s

LOPES Experiment (2004)

- 10 antennas at Kascade array.
- 40-80 MHz
- E > 10^{16} eV trigger



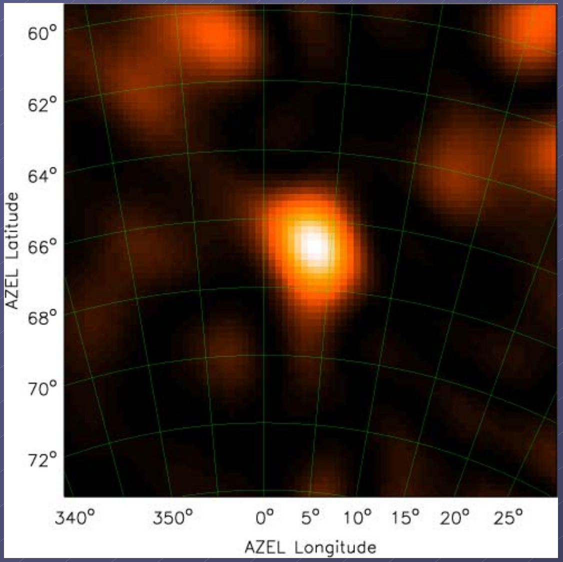


Image of single shower ~ 10^{17} eV.