

VERITAS



The HEP Cosmic Frontier
KA-13 Program

Karen Byrum

DES



SPTPol



The HEP Cosmic Frontier Experimental Program

CMB (SPTPol)

J. Carlstrom (HEP) ** (GL)

C. Chang (HEP) **

V. Novosad (MSD)

FY12 ~3.75 FTE

G. Wang (HEP)

V. Yefremenko (HEP/MSD)

Jared Mehl^(HEP) Starts soon

Dark Energy (DES/SDSS/LSST)

Kyle Barbary^(Directors Fellow w/DES group - starts Oct 2012)

R. Biswas^(HEP)

E. Kovacs (HEP)

FY12 ~3.25 FTE

K. Kuehn^(HEP)

S. Kuhlmann (HEP) (GL)

H. Spinka (HEP)

Indirect Dark Matter (VERITAS)

K. Byrum (HEP) (GL)

G. Decerprit^(ANL/DESY) - (just started at Ecole normale superieure, Paris)

R. Wagner (HEP)

FY12 ~2.5 FTE

B. Zitser^(HEP)

GL - Group Leader

** Joint w/ Univ. of Chicago

^ Postdoctoral Fellow

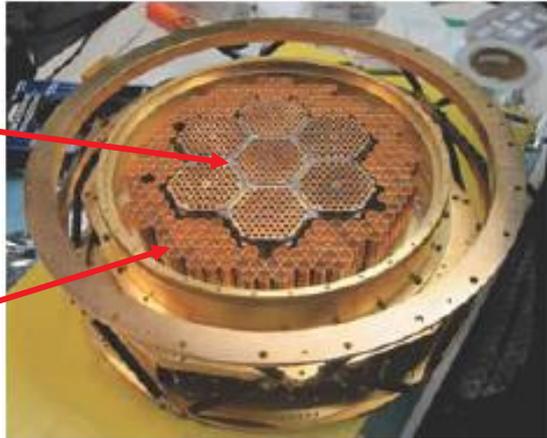
HEP - High Energy Physics Div.

MSD - Materials Science Div.

SPTPol and SPT3G

NIST 150GHz
sensors

ANL 90GHz
sensors



10 meter SPT

Present: SPTpol

- CMB Science - Inflation, DE and neutrino sector
- Led development from scratch new Focal Plane TES sensors to measure CMB polarization.
- SPTpol now taking data through 2016: Goal to detect B modes

Future: SPT3G

Unique ANL HEP Leadership Role

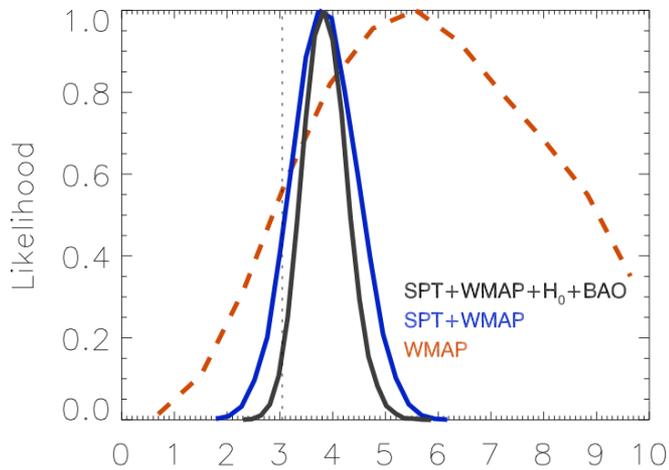
- New joint DOE/NSF proposal to upgrade SPTpol with new multichroic focal plane instrumentation.
- Utilizes unique lab resources to develop and demonstrate proof-of-concept new TES multiplexer sensors and deploy on SPT3G
- High impact for HEP science

CMB Science

Exploring the *GUT* scale, Dark Energy and the Neutrino sector.

SPT data: Use CMB power spectrum to probe early universe physics:
Primordial relativistic degrees of freedom

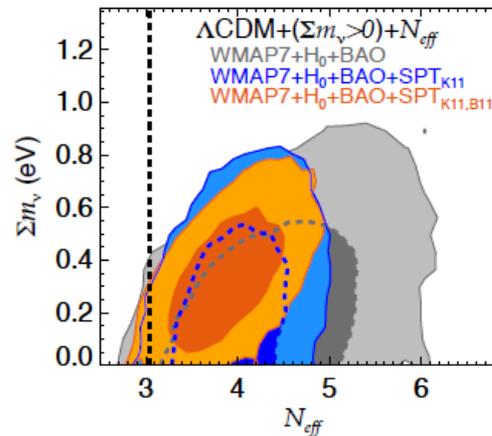
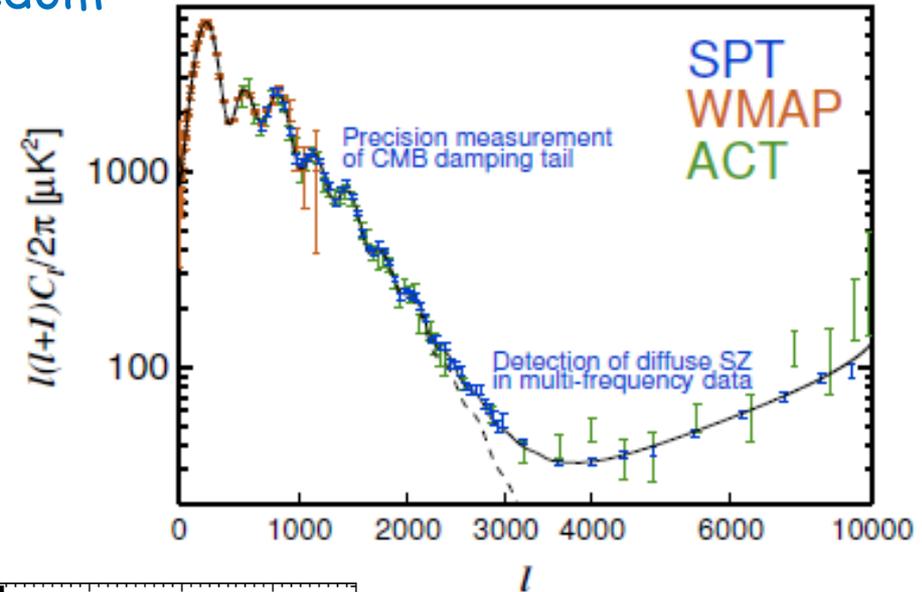
Keisler et al 2011, ApJ, 743, 28



Standard Model, 3 neutrinos.

$$N_{\text{eff}} = 3.86 \pm 0.42$$

(SPT+WMAP+H₀+BAO)



$$\sigma(\Sigma m_\nu) \sim 0.28 \text{ eV}$$

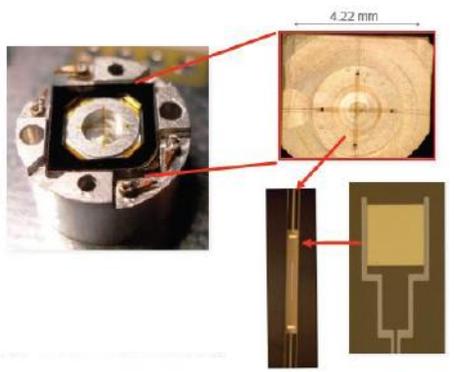
(SPT+WMAP+H₀+BAO)

Benson et al 2011,
arXiv: 1112.5435

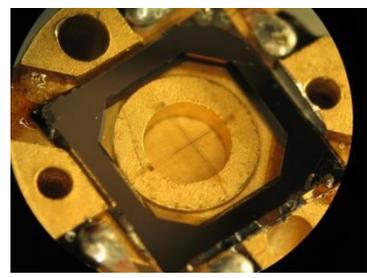
SPTpol: From concept to science



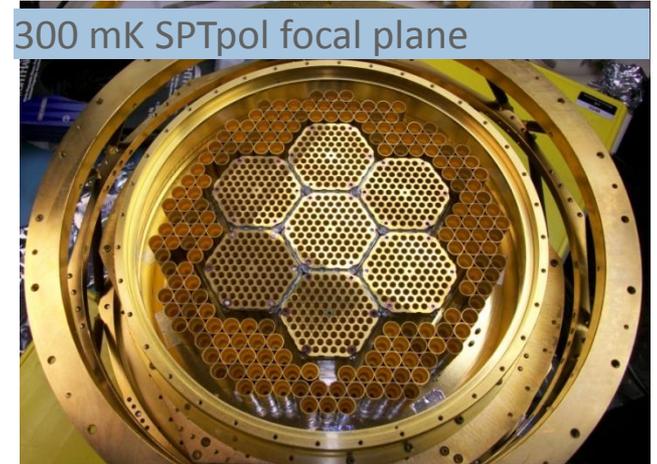
ANL 90 GHz & NIST 150 GHz; Built from Scratch; Installed last winter 2011



ANL 90 GHz Mo/Au TES bolometers developed in CNM/MSD



Production completed, delivery & cool down at SPTPol

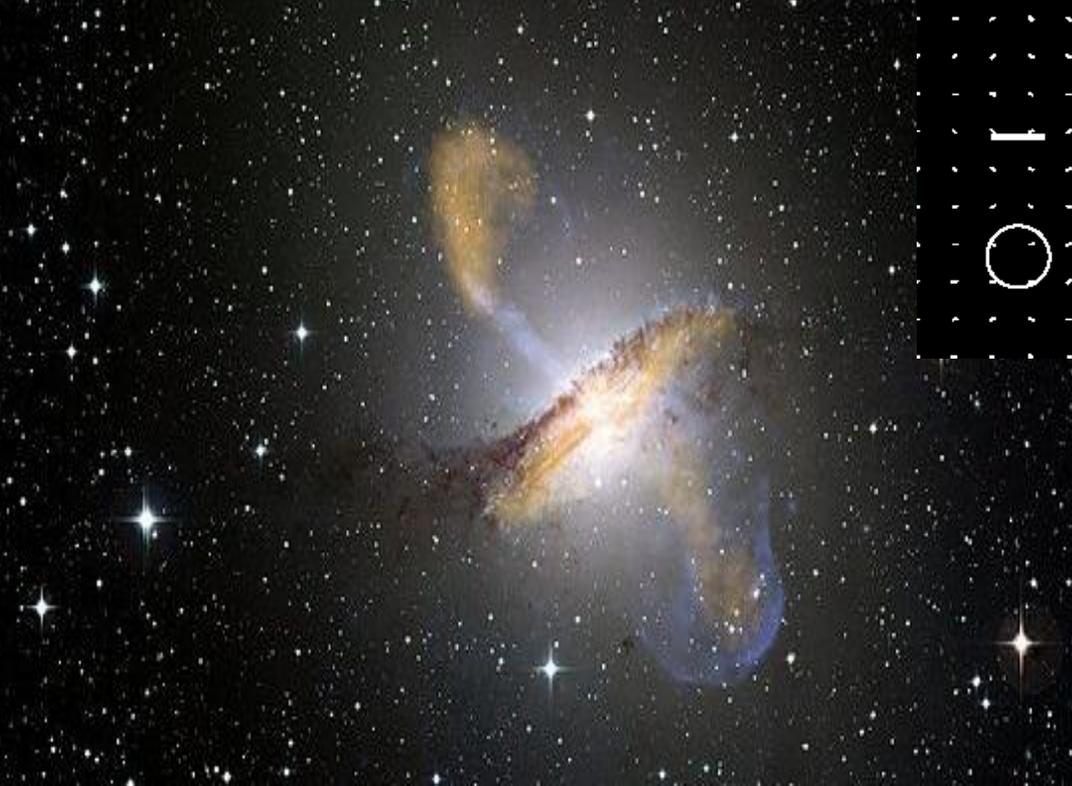


- Increase scientific reach (2x more detectors)
- Expand capabilities to measure polarization

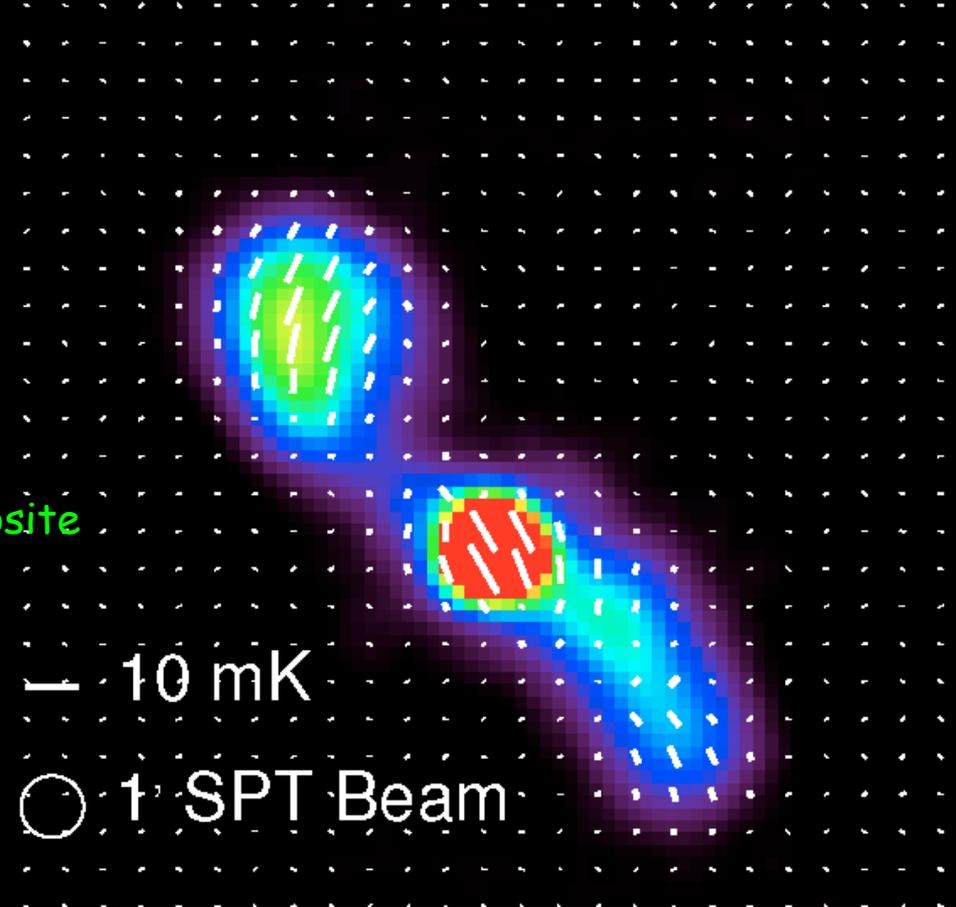
SPTpol: Delivered on time-
Significant Milestone!

Centaurus A:
Highly polarized
Radio loud galaxy

Centaurus A: Optical, X-ray, and sub-mm composite



GenA Temperature and Polarization

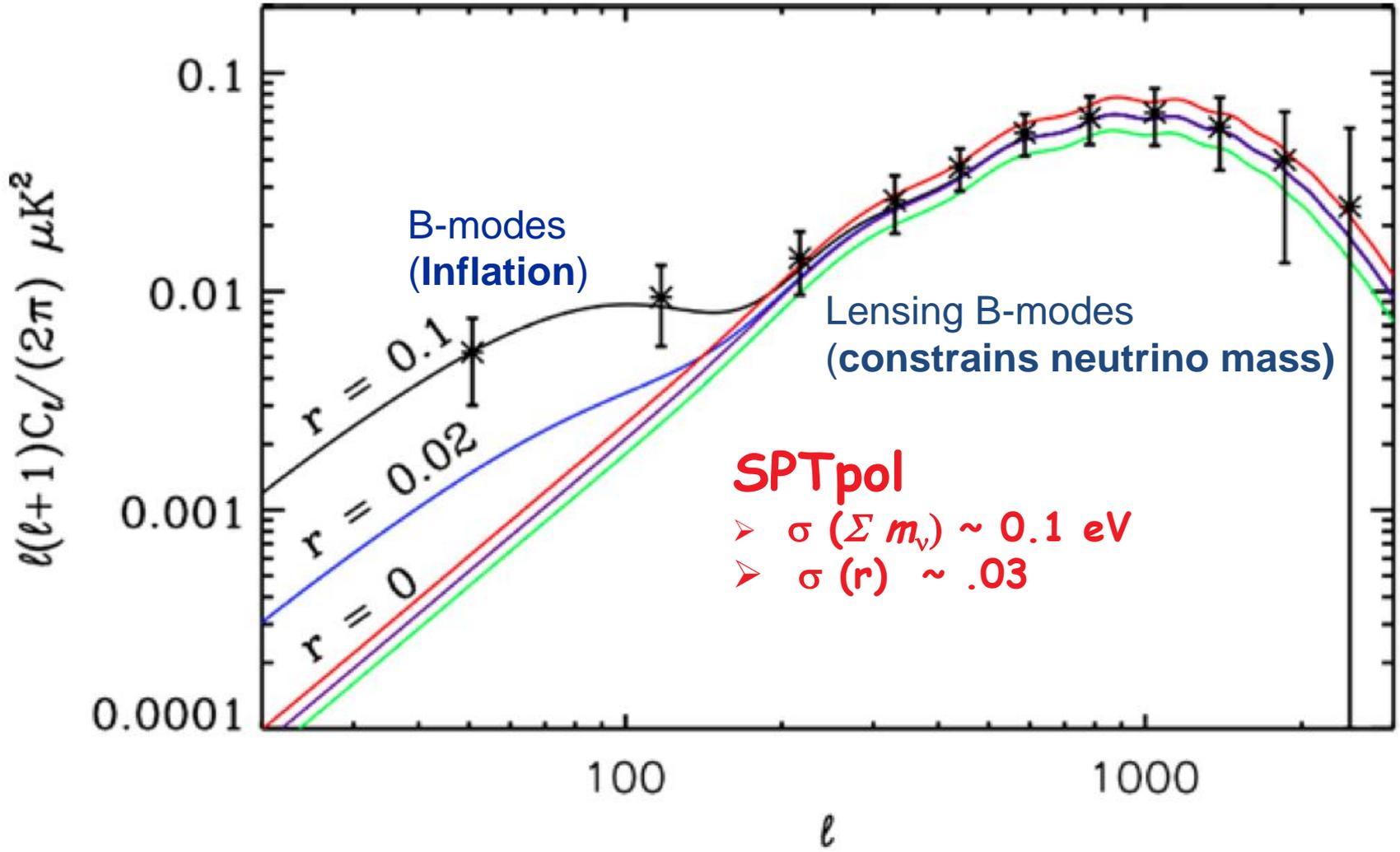


— 10 mK
○ 1 SPT Beam

SPT-POL Polarization Map

SPTpol: Detect B modes

Projected 3 year SPTpol B-mode Spectrum



Future: SPT3G

New Joint DOE/NSF proposal building upon capabilities of SPTpol group: New High Density CMB focal plane arrays for CMB science

Unique ANL HEP Leadership Role

➤ CMB Science:

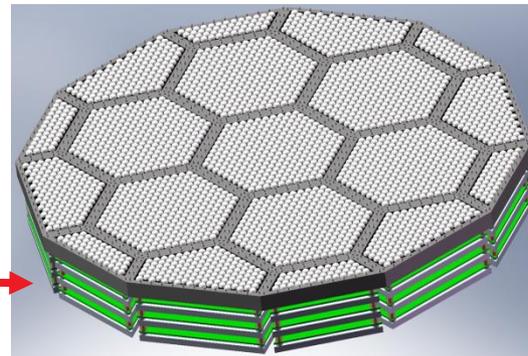
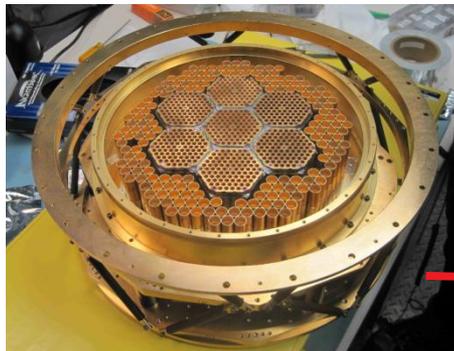
- What is the universe made of? DE, DM
- How do Neutrinos work?
- How did the Universe begin? Inflation
- Structure evolution (computational cosmology)

SPT3G Planned:
 $\sigma(\Sigma m_\nu) \sim 0.06 \text{ eV}$
 $\sigma(r) \sim .01$

➤ Enabling Technology:

- Develop new multichroic Transition Edge Sensors for higher focal plane density

2012:SPTpol
~ 1600 detectors



2016:SPT3G
~ 16,000 detectors

Dark Energy Group

Dark Energy Camera First Light This Month!

Present: DES - Stage III DE exp.

- Leading Supernova Cosmology Studies: Synergy between DES/SDSS/LSST
- Led PreCam Project: calibration camera of DES
- DECam ~20% mechanical work at ANL (6 L3 managers)
- Habib/Heitmann now DES members

Future: LSST and Stage IV Supernovae

- Leading LSST Supernova Survey Optimization
- ANL now a LSST Project member, discussing engineering roles
- R&D for Stage IV Supernovae measurements



DECam installed on telescope

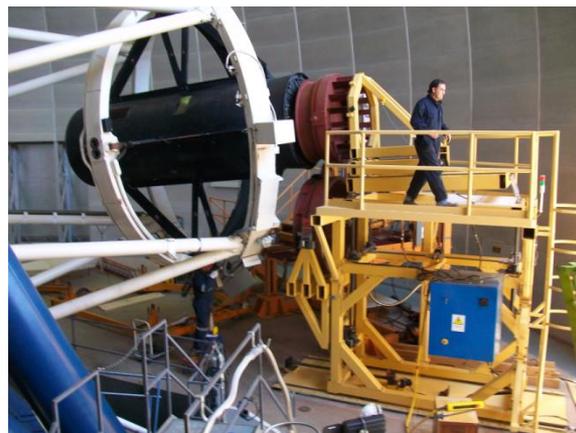


DECam in staging area

f/8 Mirror Installation Platform



f/8 mirror installation platform assembled in ANL Bld. 366



Testing at CTIO next to Blanco telescope



f/8 mirror (black) on old handling system

- Main ANL DECam project is f/8 mirror platform
 - 1-ton mirror, 6-ton installation platform
 - Alignment to 300um, robust for earthquakes
 - Mirror damaged in March with old system, being evaluated in Tucson now.
 - ANL personnel will travel to CTIO for first use with repaired or replaced mirror.



Hal Spinka at CTIO in February during final CTIO acceptance tests

PreCam, a Precursor Observational Campaign for Calibration of the Dark Energy Survey

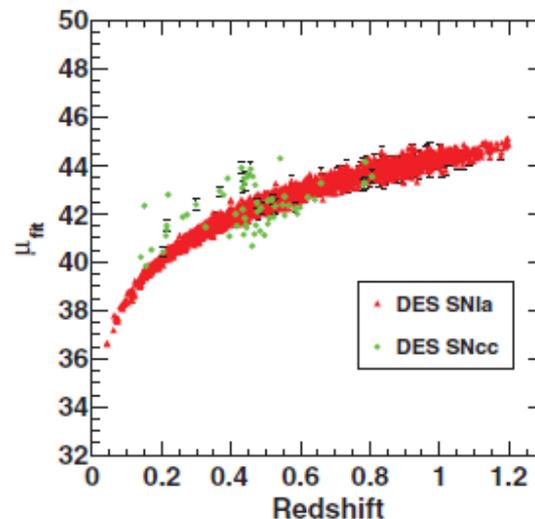
[arXiv:1208.0865](https://arxiv.org/abs/1208.0865)

[K. Kuehn](#)^{1,2}, [S. Kuhlmann](#)^{1,2}, S. Allam³, J. T. Annis³, T. Bailey^{1,4}, E. Balbinot^{5,6}, J. P. [Bernstein](#)¹, T. Biesiadzinski⁷, D. L. Burke⁸, M. Butner⁹, J. I. B. Camargo^{6,10}, L. A. N. da Costa^{6,10}, D. DePoy¹¹, H. T. Diehl³, J. P. Dietrich⁷, J. Estrada³, A. Fausti⁶, B. Gerke^{8,12}, [V. Guarino](#)¹, H. H. Head⁹, R. Kessler¹³, H. Lin³, W. Lorenzon⁷, M. A. G. Maia^{6,10}, L. Maki^{7,14}, J. Marshall¹⁰, B. Nord⁷, E. Neilsen³, R. L. C. Ogando^{6,10}, D. Park^{3,15}, J. Peoples³, D. Rastawicki¹⁶, J.-P. Rheault¹⁰, B. Santiago^{5,6}, M. Schubnell⁷, P. Seitzer¹⁷, J. A. Smith⁹, [H. Spinka](#)¹, A. Sypniewski⁷, G. Tarle⁷, D. L. Tucker^{3,2}, A. Walker¹⁸, W. Wester³
(the Dark Energy Survey Collaboration)

- Argonne designed and built/tested 2-DECam-CCD camera
- Grid in DES area, x100 increase in calibration stars
- 2-2.5% precision with 4 visits in g,r,i filters. Fermilab simulations show ~5% precision in 2 years without PreCam.
- Kuhlmann and Dave Burke (SLAC) leading proposal for second season to complete 10 grid visits (<1.5% precision).
- Depends on competition for telescope, decision 2013

Supernova Cosmology

- 5 SNe papers since May 2011 (2 ANL first-author)
 - ANL-led long DES strategy paper published (ApJ)
 - Now applying same tools to LSST strategy
- Detailed systematic studies by Rahul Biswas retraining the SALT Type Ia model adding SDSS data.
 - Important study for DES SN systematics.
- Kuhlmann second SN-science member of Dark Energy Science Task Force, along with Saul Perlmutter.
- Kyle Barbary, Perlmutter's student, starts this fall as ANL Director's Fellow



Projected DES Hubble Diagram

THE ASTROPHYSICAL JOURNAL, 752:1 (25pp), 2012 ???
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doi:10.1088/0004-637X/7?

SUPERNOVA SIMULATIONS AND STRATEGIES FOR THE DARK ENERGY SURVEY

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 D. A. FINLEY⁷, J. A. FRIEMAN^{2,3,7}, T. HUFFORD¹, M. J. JARVIS^{8,9}, A. G. KIM⁴, J. MARRINER⁷, P. MUKHERJEE¹⁰, R. C. NICHOLSON¹¹,
 P. NUGENT⁴, D. PARKINSON¹⁰, R. R. R. REIS^{7,13}, M. SAKO¹¹, H. SPINKA¹, AND M. SULLIVAN¹²

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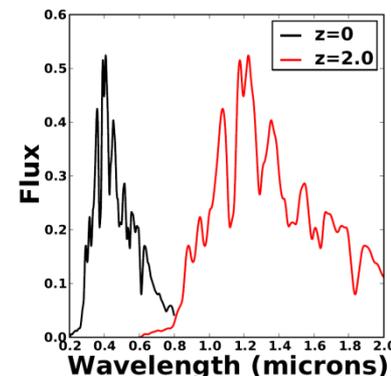
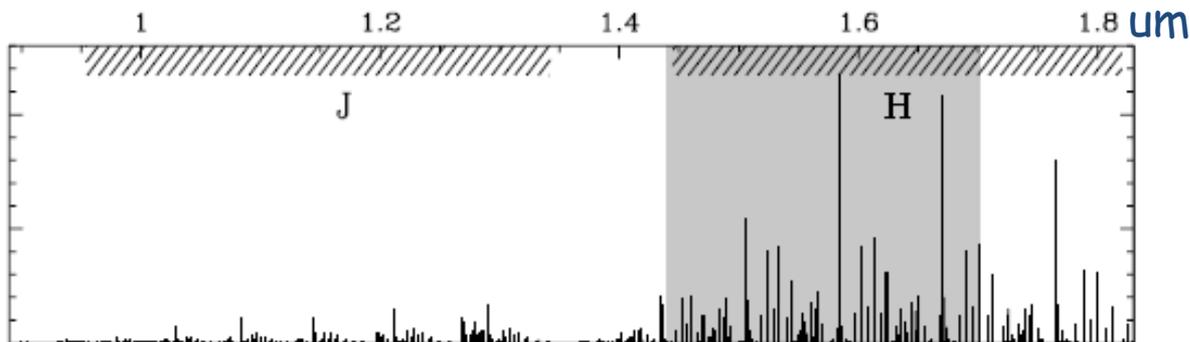
¹² Department of Physics, Denys Wilkinson Building, Oxford University, Keble Road, Oxford OX1 3RH, UK

Received 2011 November 5; accepted 2012 May 7; published 2012 ???



Future R&D to Reach DETF Stage IV Level Supernova

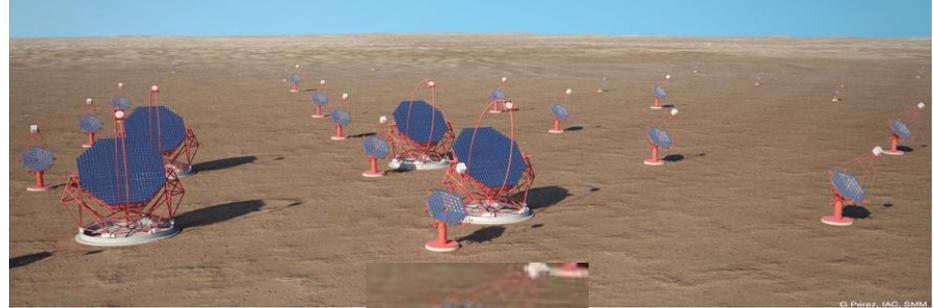
- Rocky Kolb, Dark Energy Science Task Force Report, HEPAP
 - Advance SN technique to Stage IV:
 - Clearest Path: Space-based mission for SNe
 - In parallel, *"explore vigorously ground-based alternatives (R&D effort for near-IR technology and sky-line suppression)"*
- Director's Fellow Kyle Barbary has worked on ground-based methods.
- Idea is to surgically suppress the narrow spikes in IR range, done routinely in telecommunications near 1.5 μ m.
- Pursuing ideas with ANL Center for Nanoscale Materials



SN spectrum at low and high redshift, need high redshift to get to Stage IV level

VERITAS and CTA

US invented this field (with DOE & NSF support)



ANL-DESY-Saclay
design

Present: VERITAS

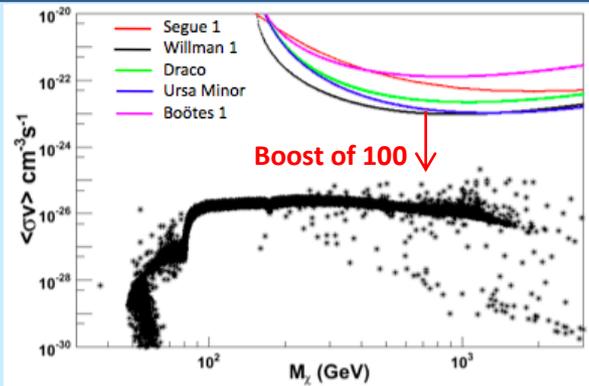
Has been the most sensitive TeV Observatory in the world.

- Science - Continued Data analysis focusing on DM, LIV and fundamental physics
- Led (w/ISU) L2 trigger upgrade for VERITAS: Now Mostly Commissioning

Future: CTA-World community building a next generation array. US is part of this. Use Snowmass to help define US DM program

- DM, LIV and fundamental Science
- Topological Array Trigger
- Mechanical engineering of economical & automated structures
- New camera based on LAPPD

VERITAS Dark Matter Science



First VERITAS DM Paper.

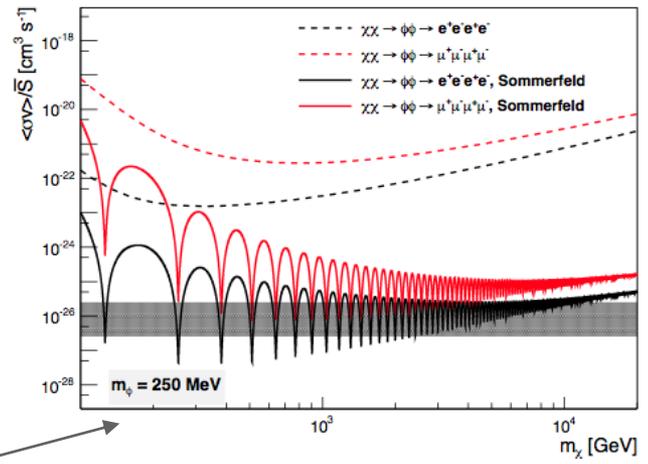
Indirect DM search using VERITAS dwarf spheroidal data ApJ 720 (2010) 1174

R.Wagner & A.Smith led analysis and paper writing

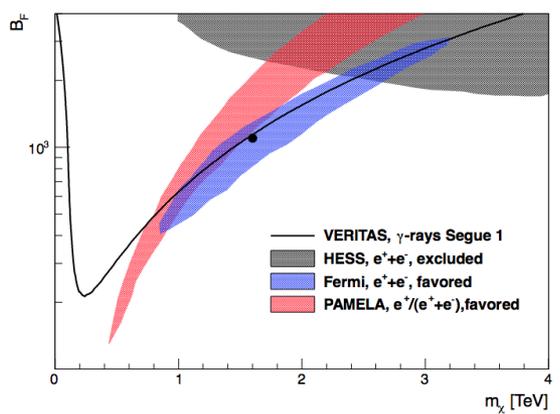
VERITAS Deep Observations of Segue 1; Phys Rev D, 85, 062001 (2012)
M. Vivier (Delaware)

- VERITAS excludes two resonances in the W+W- production
- VERITAS starts to disfavor models that introduce a new dark force mediated by a scalar particle $M_\phi \sim 250$ MeV

Internal Brem and Sommerfeld models predict DM enhancement



Leptophilic DM models (annihilation exclusively into muons): VERITAS muon model exclusion curve to constrain the allowable boost factors

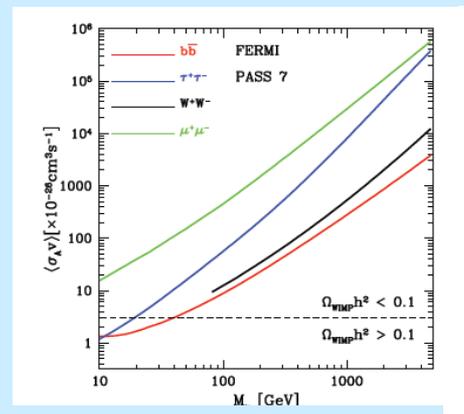


ANL and Brown Univ.

Use frequentist-statistics method on the VERITAS dwarfs to extend the Fermi limits into the high mass region available to VERITAS.

Brown - method for stacking
Argonne - data analysis (PSF, acceptances, etc..) & systematics (Decerprit & Zitzer)

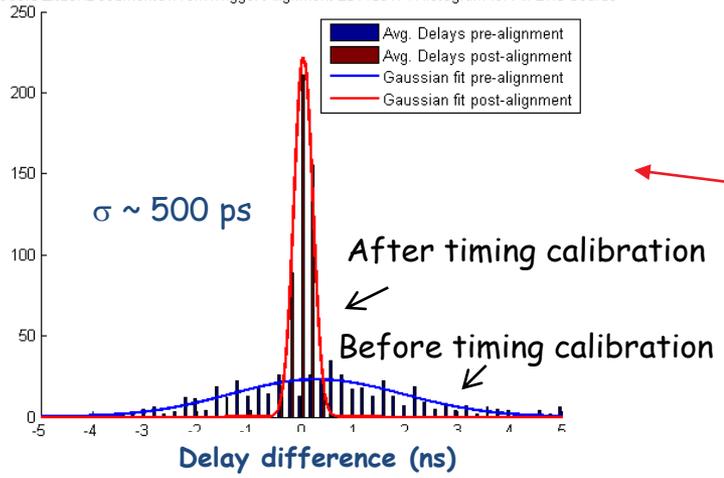
Exclusion of WIMPs $w/M < 40$ GeV using FERMI Dwarf data



Geringer-Sameth and Koushiappas, PhysRevLett 107.341302 (Brown)

VERITAS Upgrade: New FPGA L2 Trigger

C:\Users\Zitzer\Documents\Work\Trigger\Alignment 20110917\ Histogram for All L1.5 boards

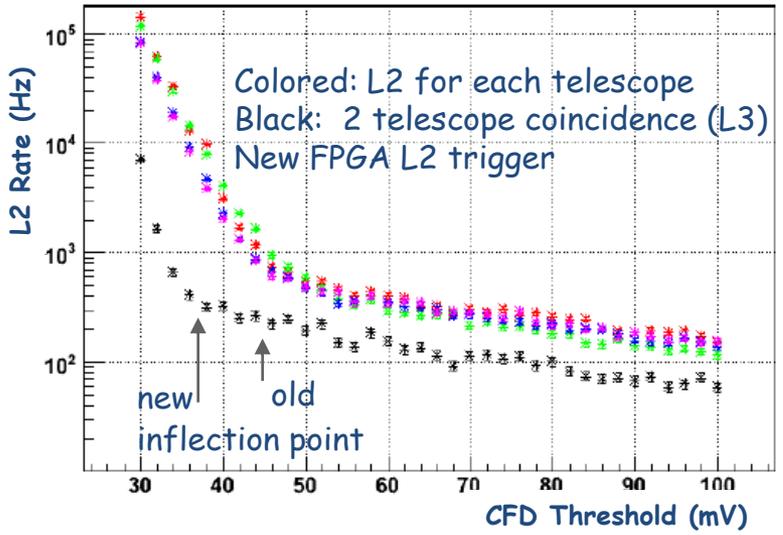


New trigger installed Nov 2011; Came up working.

GOALS: Ability to lower energy threshold & Improved trigger performance

- precision pixel to pixel alignment of < 1ns
- Adjustable 3-pixel coincidence gate down to 3ns
- All hooks in place to add a topological array trigger

• Commissioning still underway; new high QE PMT camera installation just completed (summer 2012).



Current VERITAS triggering Energy threshold:

$$E_{\dagger} \sim 130 \text{ GeV @ } 50\text{mV CFD}$$

With new trigger:

$$E_{\dagger} \sim 90\text{-}100 \text{ GeV @ } 40\text{-}45\text{mV CFD}$$

ANL(hardware)/ISU(software)

Anderson, Drake, Zitzer, Byrum (ANL) with Krennrich, Orr, & Weinstein (Iowa State Univ.)

Future: CTA (Indirect DM Detector)

World wide gamma-ray community:
Fermi/HESS/MAGIC, VERITAS

985 collaborators, 163 institutions, 26 nations
US - CTA group: 22 instit. (including 2 labs)
approaching 100 collaborators

NSF recently funded (\$4M + matching) MRI for US-CTA collaboration to build novel dual-mirror telescope to site at VERITAS.

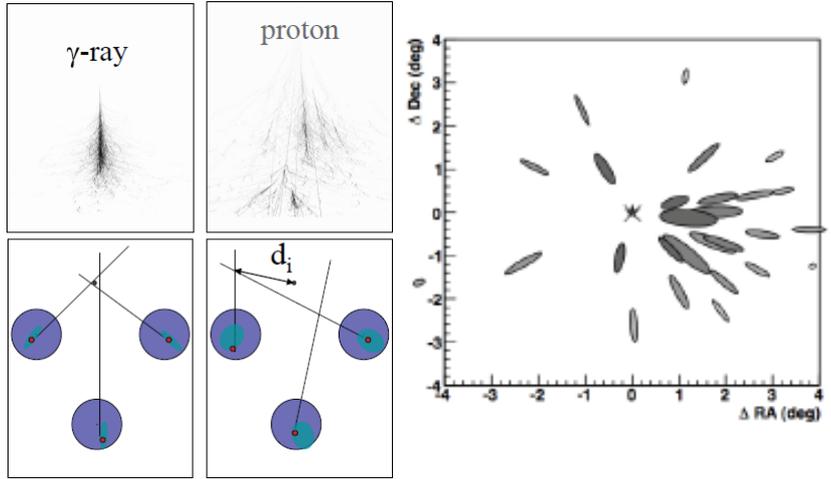
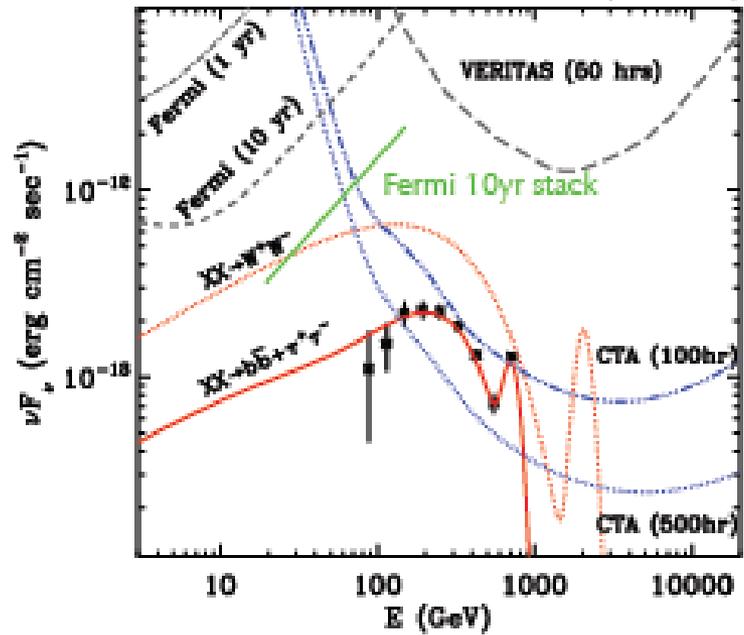
Argonne's role: Lead the Mech. Design of Structure (L2 WBS manager), Develop a Topological trigger (w/ISU)

Topological Trigger (ANL/ISU: Builds upon L2 VERITAS trigger)

➤ **Array Trigger Concept: Use Parallax at trigger level**
(simulations predict order of mag. cosmic-ray reduction, keeping 90% of gammas)

Dwarf Galaxy with Future ACT

(JB, 2011)



Multiple telescope images line up

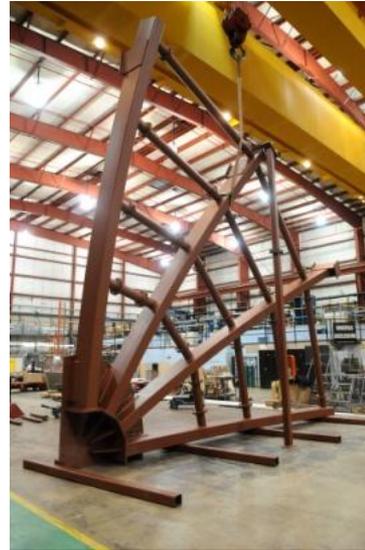
ANL leading CTA Mechanical Design of Structure

CTA 12m Davies-Cotton
ANL/DESY/CEA Design



Work started with LDRD
and DESY support.

NSF is funding ANL to
perform mech. Designs
within MRI

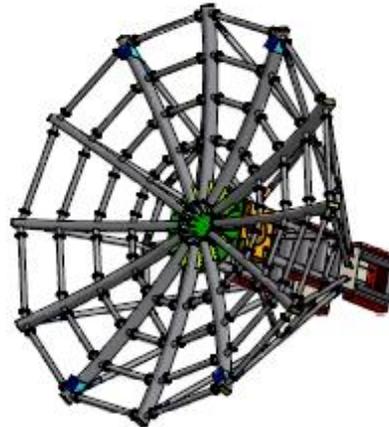
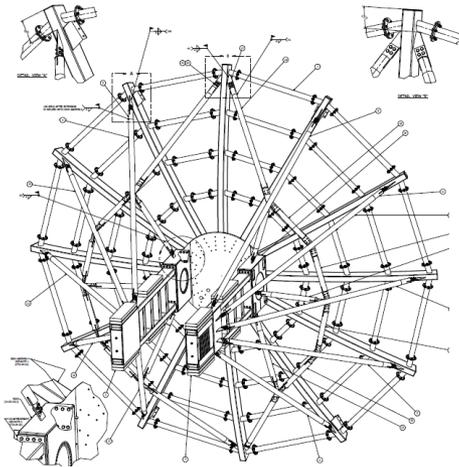


Quarter dish
for DC
telescope. All
components
built in Chicago
based US
industry.



Quarter dish reassembled
in Berlin.

Final Design DC Drawings



➤ DC telescope being constructed in
Berlin this fall.

➤ MRI funding for US led dual
mirror design just beginning!

Summary: ANL Contributions to Cosmic Frontier: *Development of "Enabling Technologies" driven by "Science"*

- **Leading development of multi-choric Transition Edge Sensors for CMB**
- **Inflation and neutrino mass with SPTpol:**
 $\sigma(\Sigma m_\nu) \sim 0.1 \text{ eV}, \quad s(r) \sim .03$
- **Leading Supernova Cosmology Simulations**
- **SN1a purity with DES better than 98% for DE FoM**
- **Led PreCam: Calibration camera for DES**
- **DES SN systematic targeting better than 1% because of PreCam**
- **Leading New Novel designs & instrumentation techniques for CTA**
- **CTA provides complementary measure of DM with sensitivity better than SUSY parameter space**

