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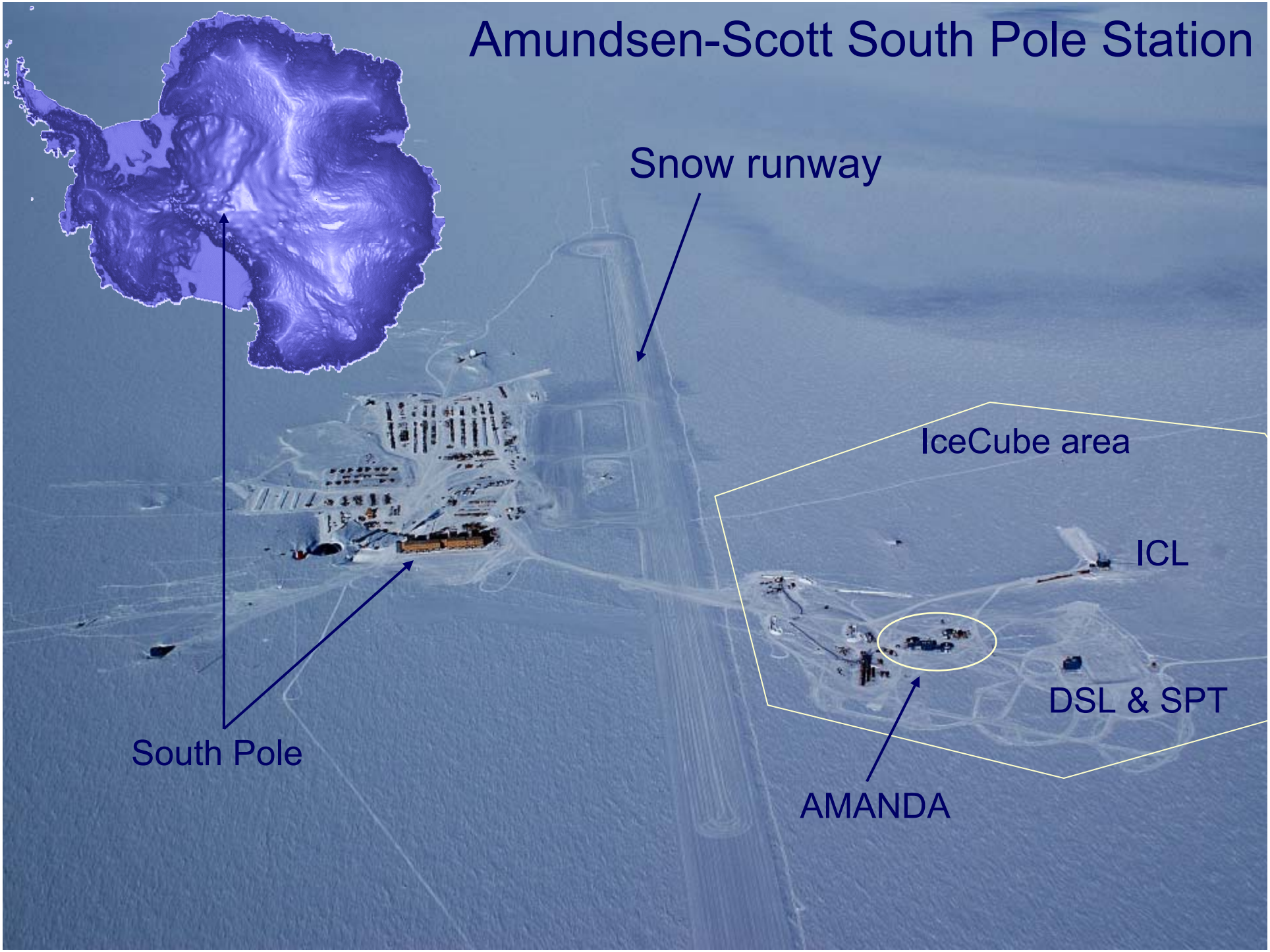
Astronomy and Astrophysics Advisory Committee
February 18, 2009

Astronomy and Astrophysics in Antarctica

Austral Summer 2008/09 Results

Vladimir Papitashvili, Program Director
Antarctic Aeronomy & Astrophysics
Scott Borg, Division Director
OPP Antarctic Sciences


Amundsen-Scott South Pole Station
Snow runway
IceCube area
ICL
DSL & SPT
South Pole
AMANDA

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NSF/OPP Antarctic Astronomy & Astrophysics

- **MREFC Project - IceCube Neutrino Observatory**
  Univ. of Wisconsin-Madison and IceCube Collaboration
- **10-m submm-wave South Pole Telescope (SPT)**
  Univ. of Chicago - Kavli Institute for Cosmological Physics
- **Gravitational Wave Background Telescope BICEP**
  (Background Imaging of Cosmic Extragalactic Polarization)
  California Institute of Technology Observational Cosmology Group
- **PLATO site-testing module at Dome A**
  (PLATeau robotic Observatory) Univ. of South Wales (Australia)
- **NASA's Long-Duration Ballooning at McMurdo**

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IceCube Neutrino Observatory

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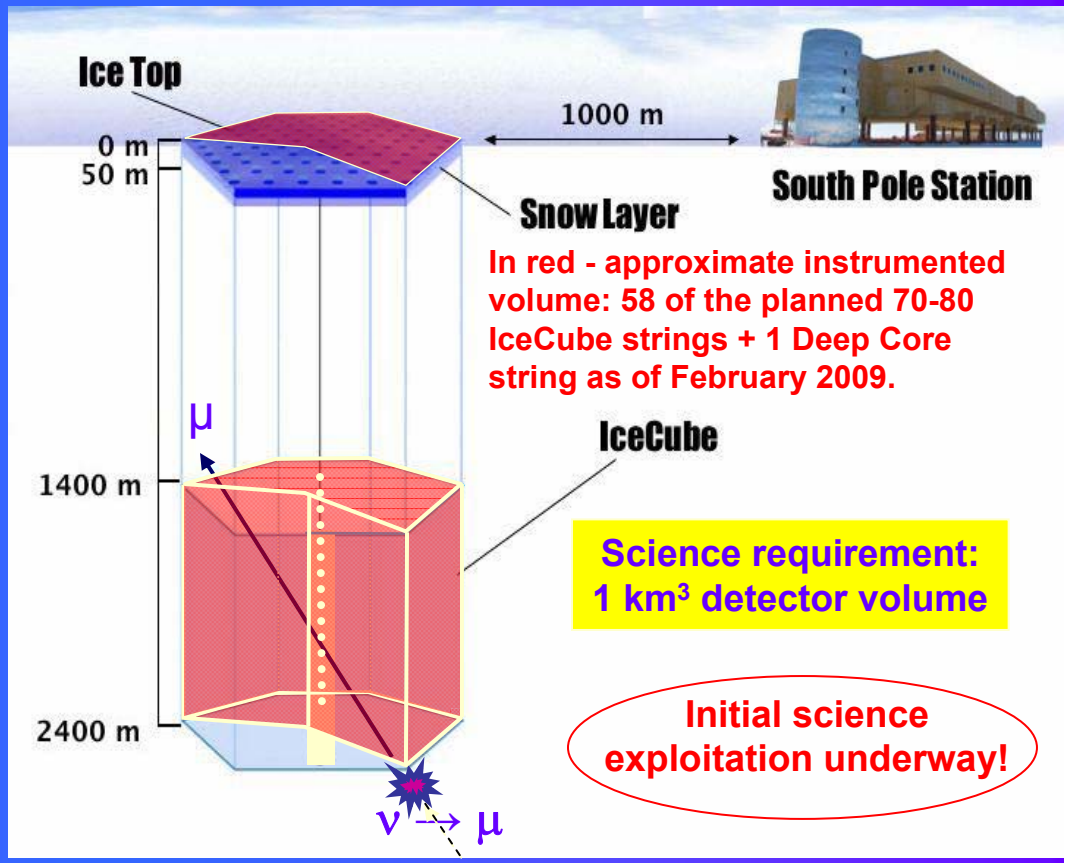
Recent Accomplishments

- Excellent austral summer season 2008/09 – 19 new DOM strings are deployed
- ICNO operations and scientific research are fully underway
- New window on the Universe is now open!

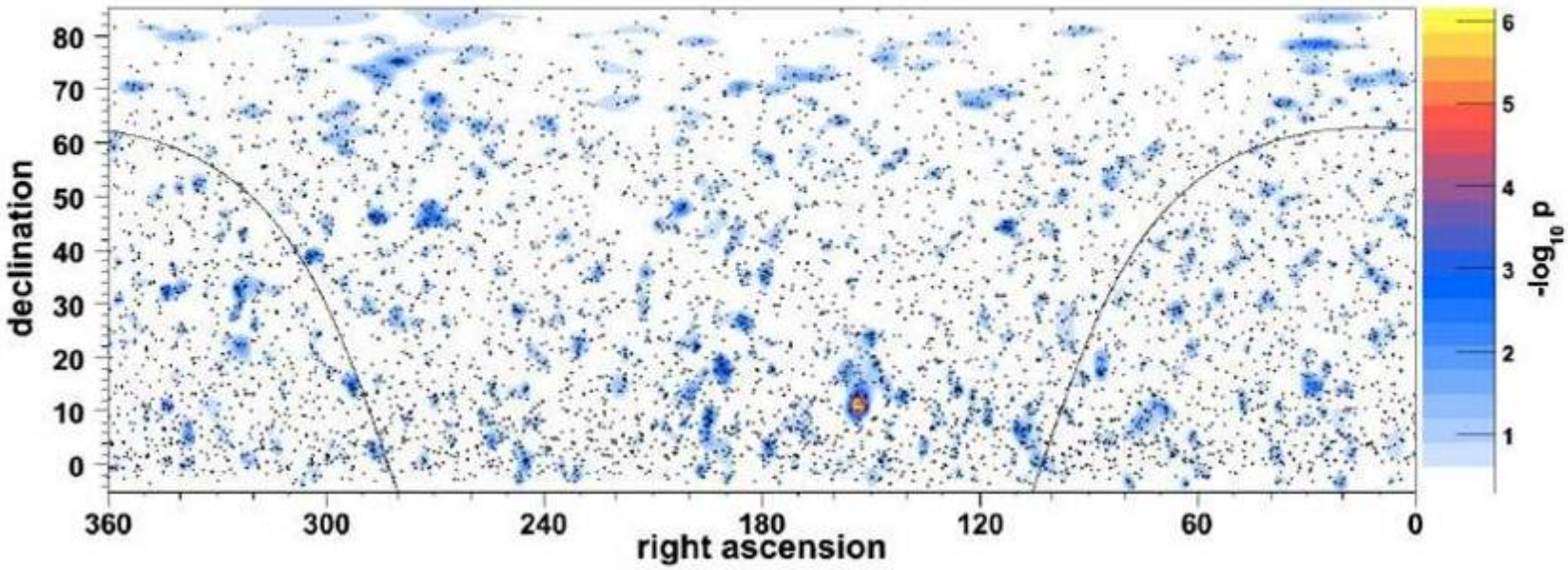


IceCube will occupy a volume of one cubic kilometer. Here we depict one of the 70-80 strings of optical modules (number and size not to scale). IceTop located at the surface, comprises an array of sensors to detect cosmic ray air showers. It will be used to calibrate IceCube and to conduct research on high-energy cosmic rays.

IceCube Supersedes AMANDA

Upgoing Events

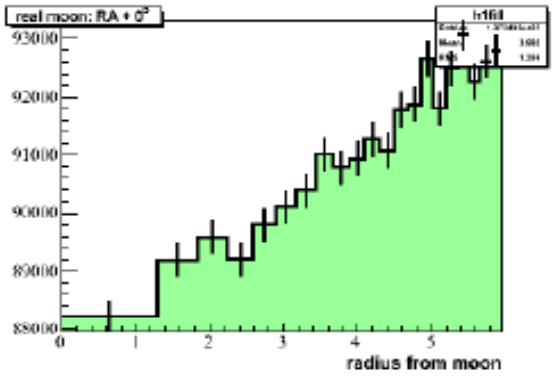
IceCube 22 String

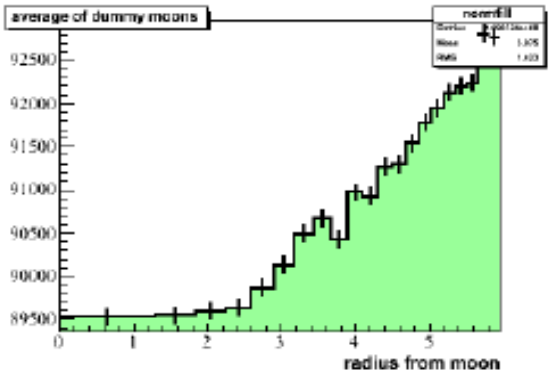


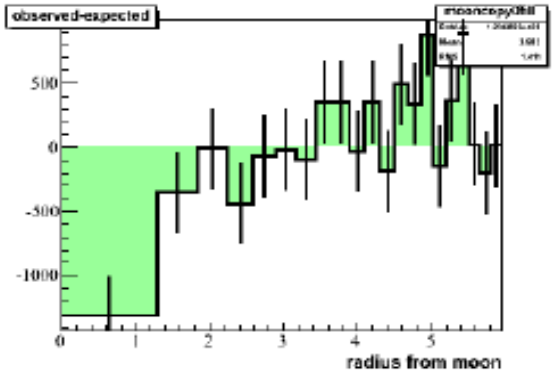
The map of Northern sky (as seen by IceCube through the Earth) shows the arrival directions of all neutrinos detected. The "hottest spot" in the map, at a location of 153° right ascension and 10° declination, represents an excess of 11 events on a background of 3 atmospheric neutrino events. After taking into account all trial factors, the probability for this event to happen anywhere in the sky map is 0.01.

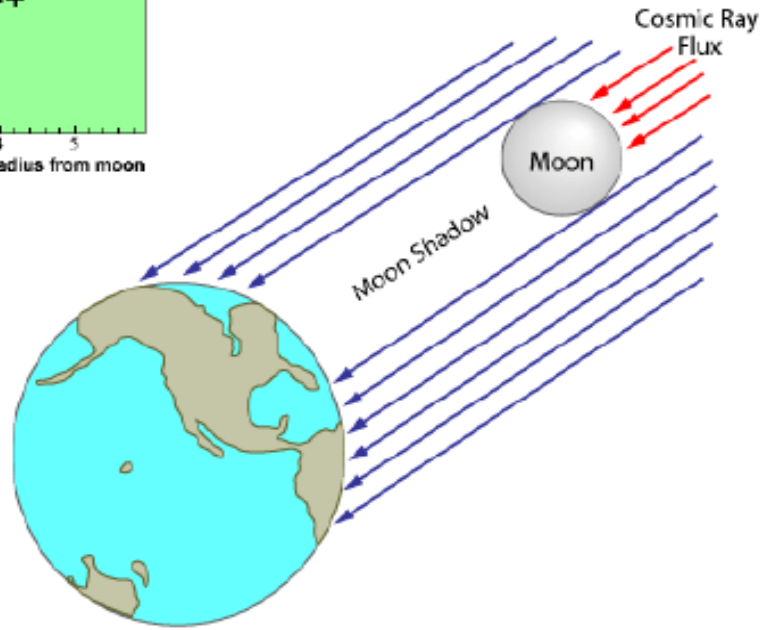
IC-40 pointing calibration

Moon Shadow









4.2σ deficit of events from direction of moon in the IceCube 40-string detector confirms pointing accuracy

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South Pole Telescope

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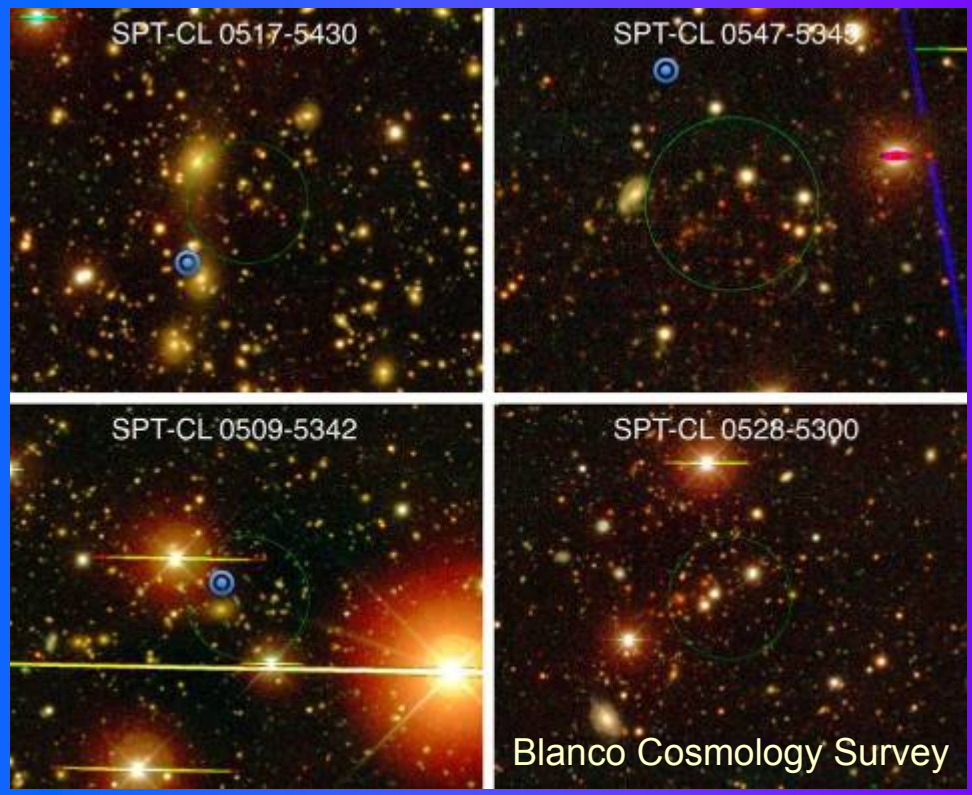
concluded its 2nd year of operations

10m Sub-millimeter South Pole Telescope:

- Recommended in 2001 Decadal Survey as Moderate Initiative ($50M)
- Funded in August 2002, first light in February 2007 - right on the budget and time!
- Confirmed viability of SZ survey strategy and began survey of galaxy clusters
- Testing various cosmological models for origin and early history of the Universe and searching for *Dark Energy* equation of state

SPT - Galaxy clusters discovered via SZE

- A major goal of the SPT project is to measure the abundance of massive galaxy clusters throughout the history of the universe.
- The SPT detects galaxy clusters through their interaction with CMB photons – the process known as the Sunyaev-Zel'dovich effect.
- The first major scientific results from the SPT initial survey were released on October 10, 2008 (submitted to *Astrophys. Journal*)
- Four distant, massive clusters of galaxies were detected; three of these clusters were previously unknown systems and, therefore, represent first clusters detected using observations of SZE in the CMB photons.



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South Pole Telescope

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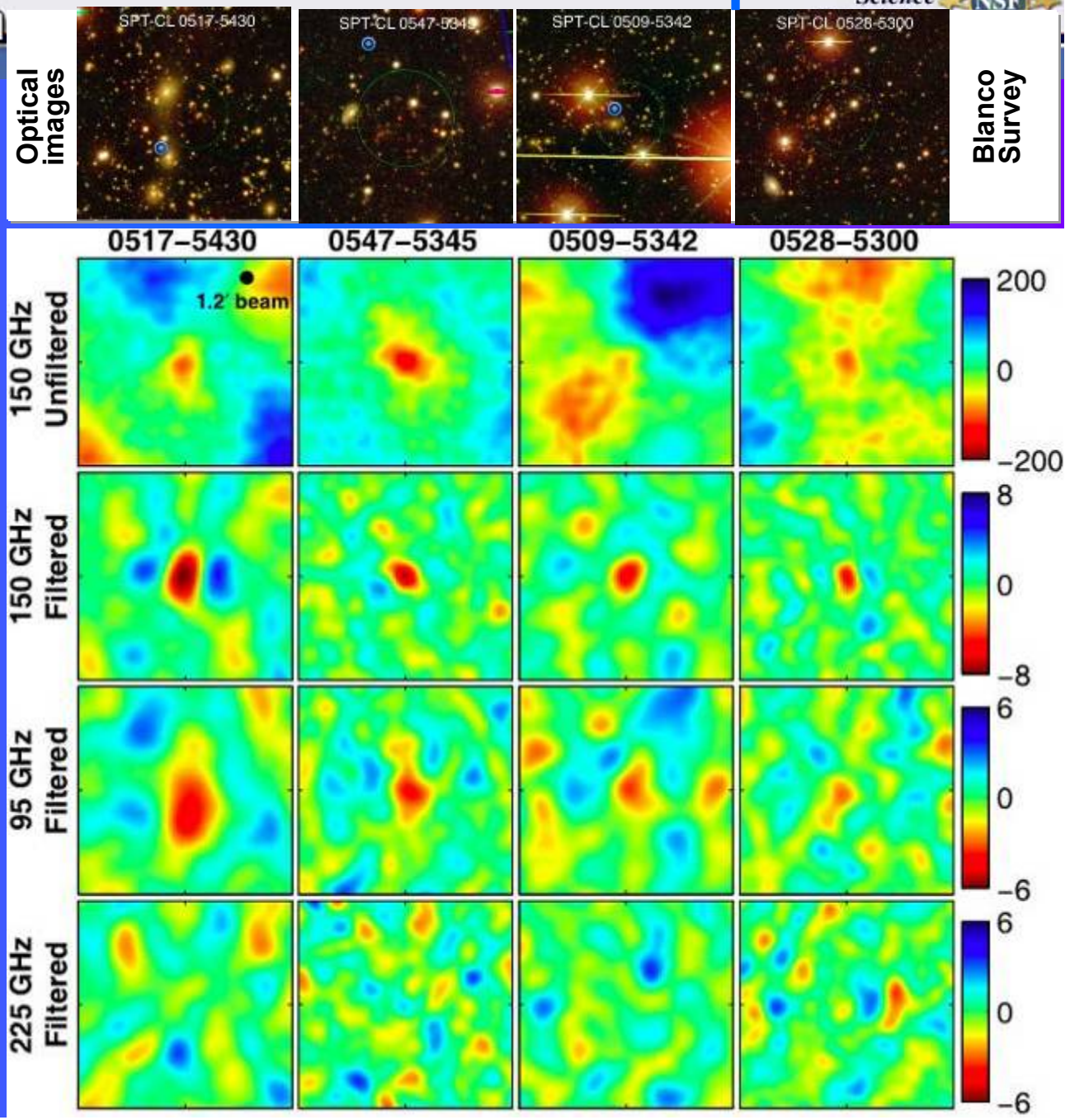
Galaxy clusters discovered via SZE

- Images of the first four SZE cluster detections in each of the three SPT observing bands.
- Cluster 0517-5430 was previously identified in the REFLEX X-ray cluster survey.



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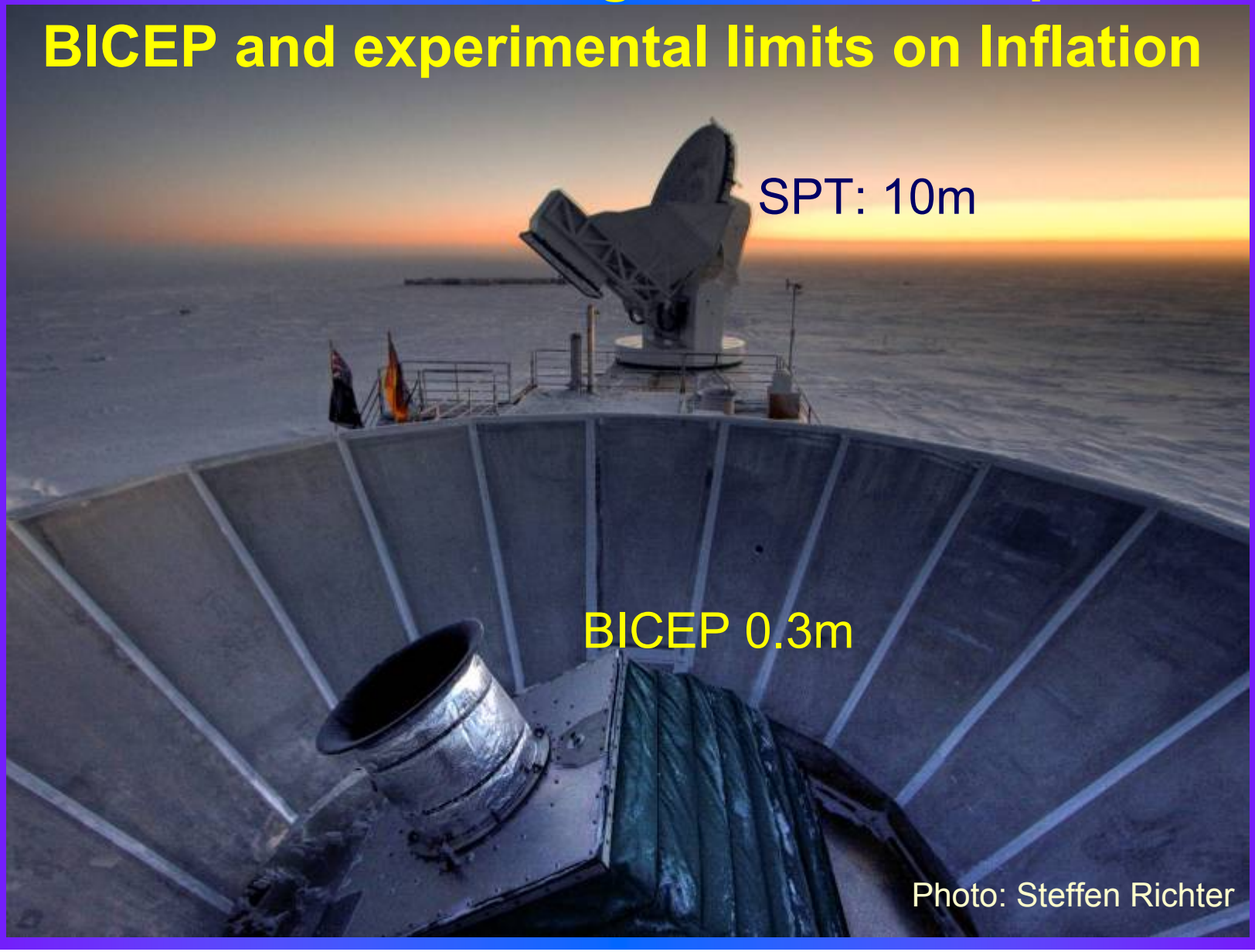
Gravitational Waves

Background Telescope

BICEP and experimental limits on Inflation



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CMB Interagency Task Force Report

July 2005

In 2007-2008, BICEP1 produced maps of CMB polarization with unprecedented sensitivity - noise level is achieved well below 1 μK in 1x1 degree pixels

3.5 years later - Progress has been much faster than expected!

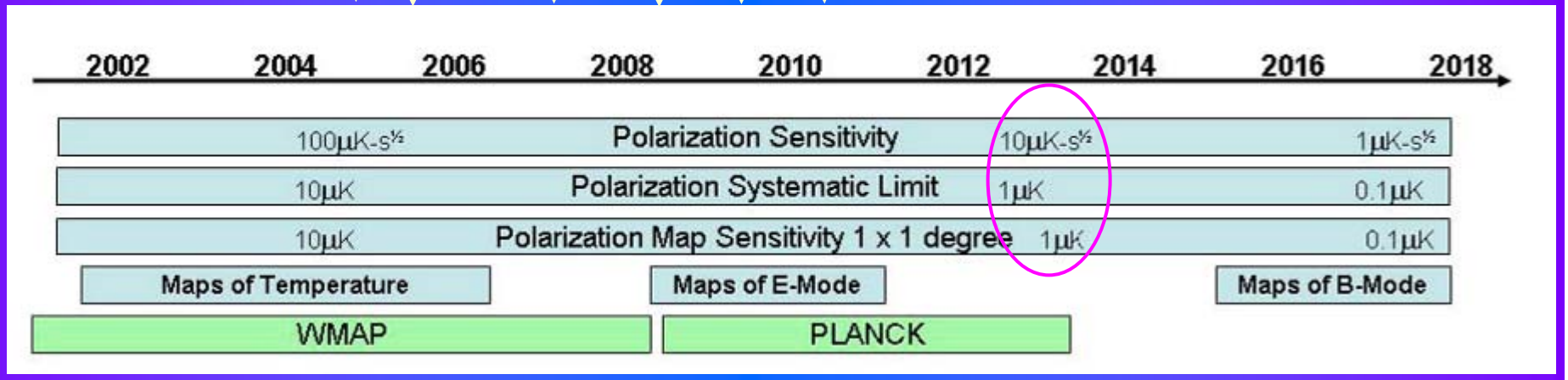
BICEP1 deployed, Nov 2005

2013 goals achieved in 2007 (2 yrs *vs.* 8 yrs)

BICEP1 redeployed, Dec 2008

BICEP2 will be deployed, Dec 2009

SPUD1 will be deployed, Dec 2010



CMB Task Force Report , Fig. 10.2

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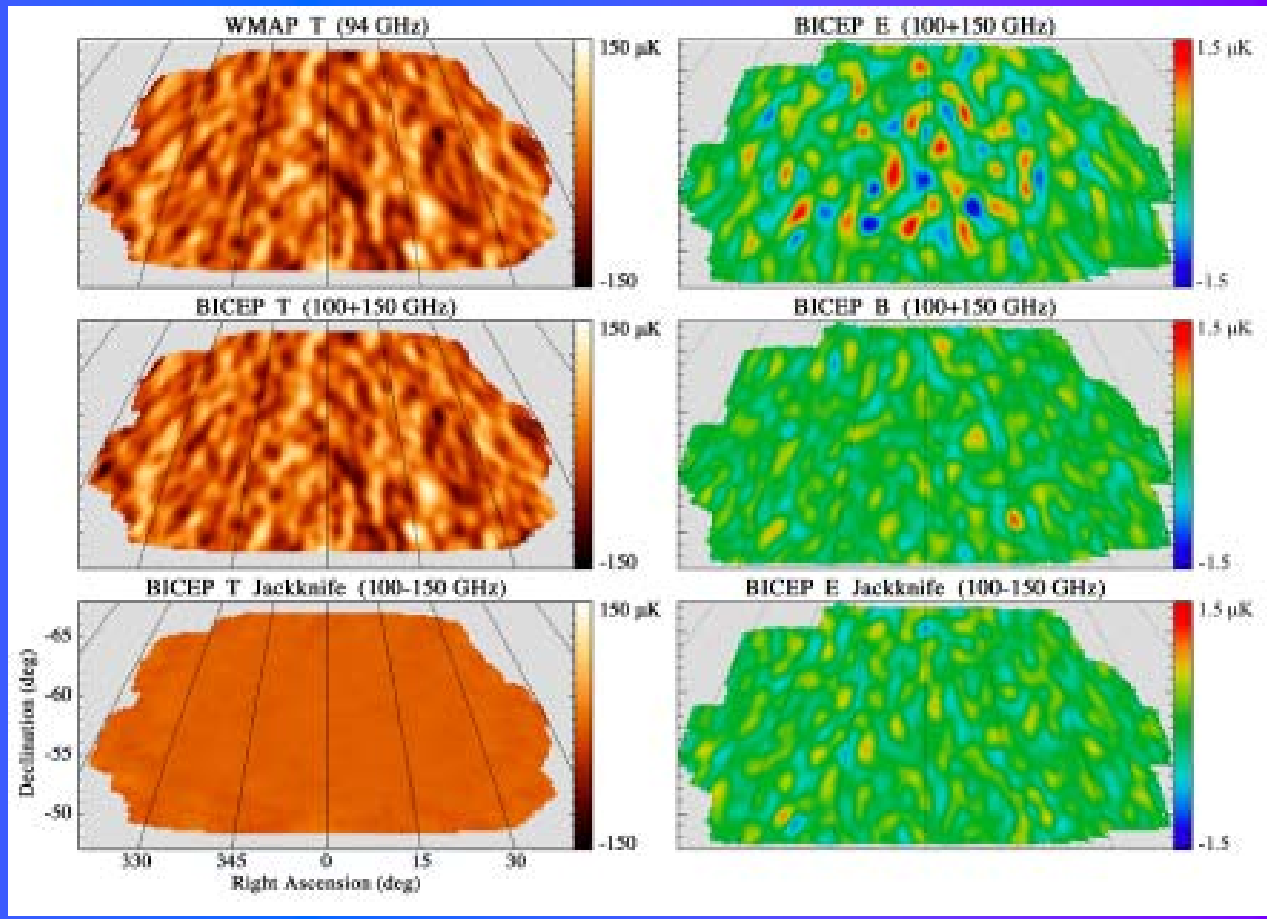
Gravitational Waves

Background Telescope BICEP

- In 2007-2008, produces CMB polarization maps of unprecedented sensitivity, achieving noise levels well below 1 mK in 1x1 deg pixels. E-mode polarization, which arises from well-known physics in the early Universe, is plainly visible at these maps. B-mode polarization is expected to be far fainter - none is apparent in these maps.
- Maps of CMB temperature (left) and polarization (right) of deep BICEP observations
- BICEP's high sensitivity is illustrated by low residuals in the 100-150 GHz difference map (bottom left) that allows to measure 100x fainter degree-scale E-mode polarization pattern (right).
- Jackknife-derived 1 sq. deg. noise is in line with team's expectation:

  100 GHz 0.78 μK

  150 GHz 0.62 μK



- BICEP2/SPUD is funded in FY08; to be deployed in Dec 2009 and observe up to 2012.

BICEP1: Polarization Experiment

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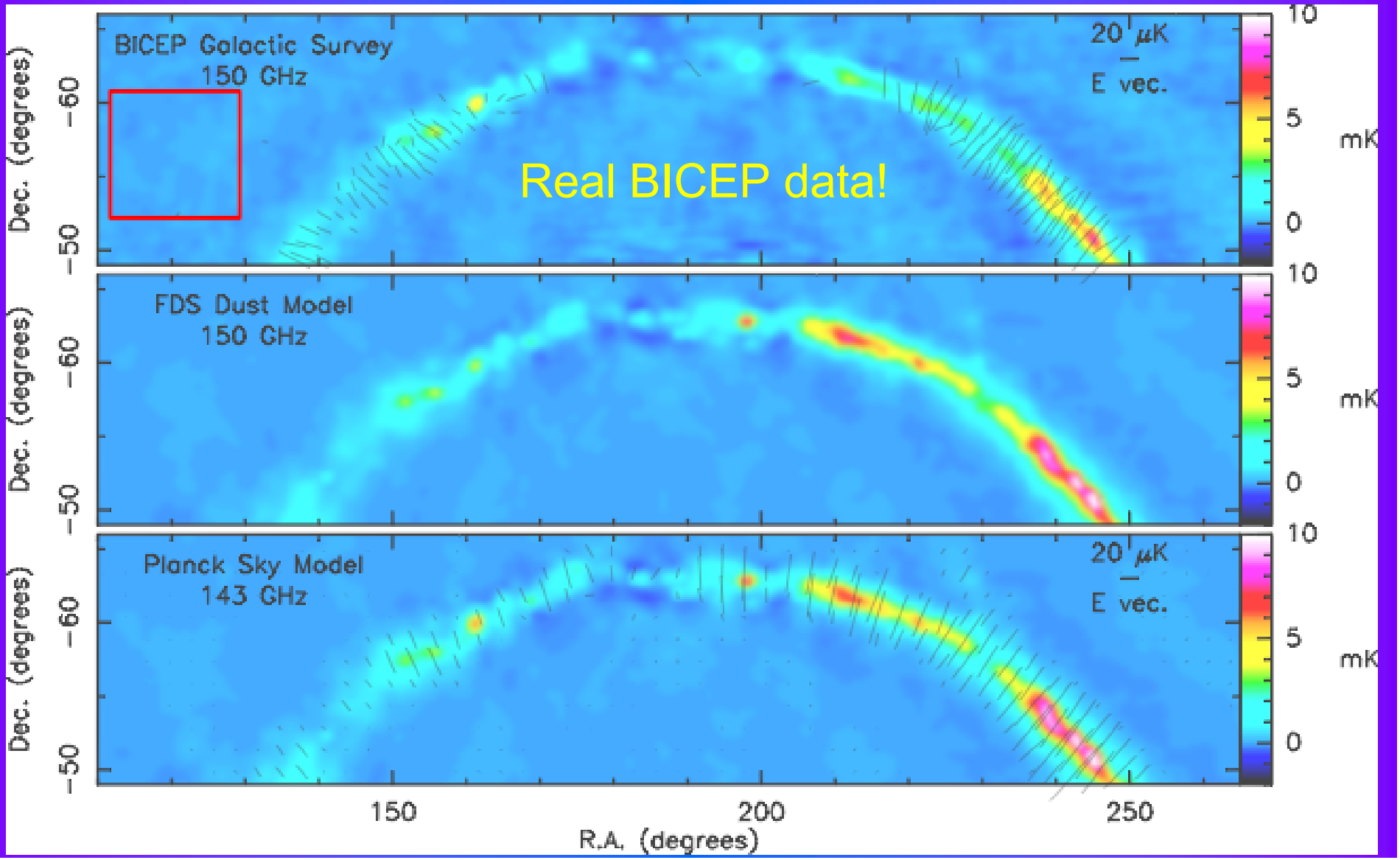
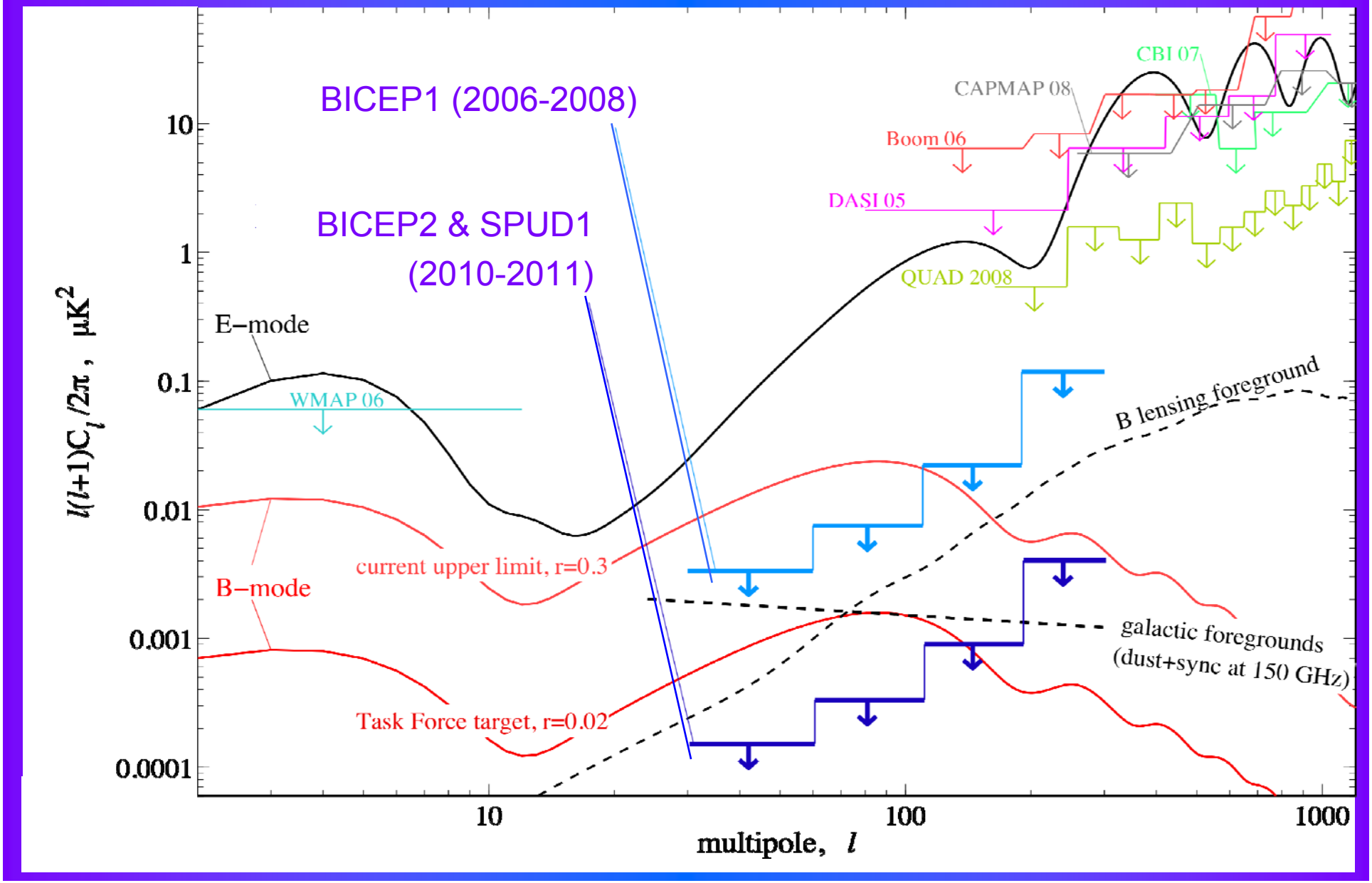
Polarization in the plane of the Galaxy is at the less than expected levels



Caltech BICEP Team's Goal



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Australian PLATO

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at Antarctic highest (4-km) Dome A

- Joint Australian – Chinese – USA project
- Total 3.5 GB of data were transmitted in 2008 via the Iridium modem provided by the U.S. Antarctic Program

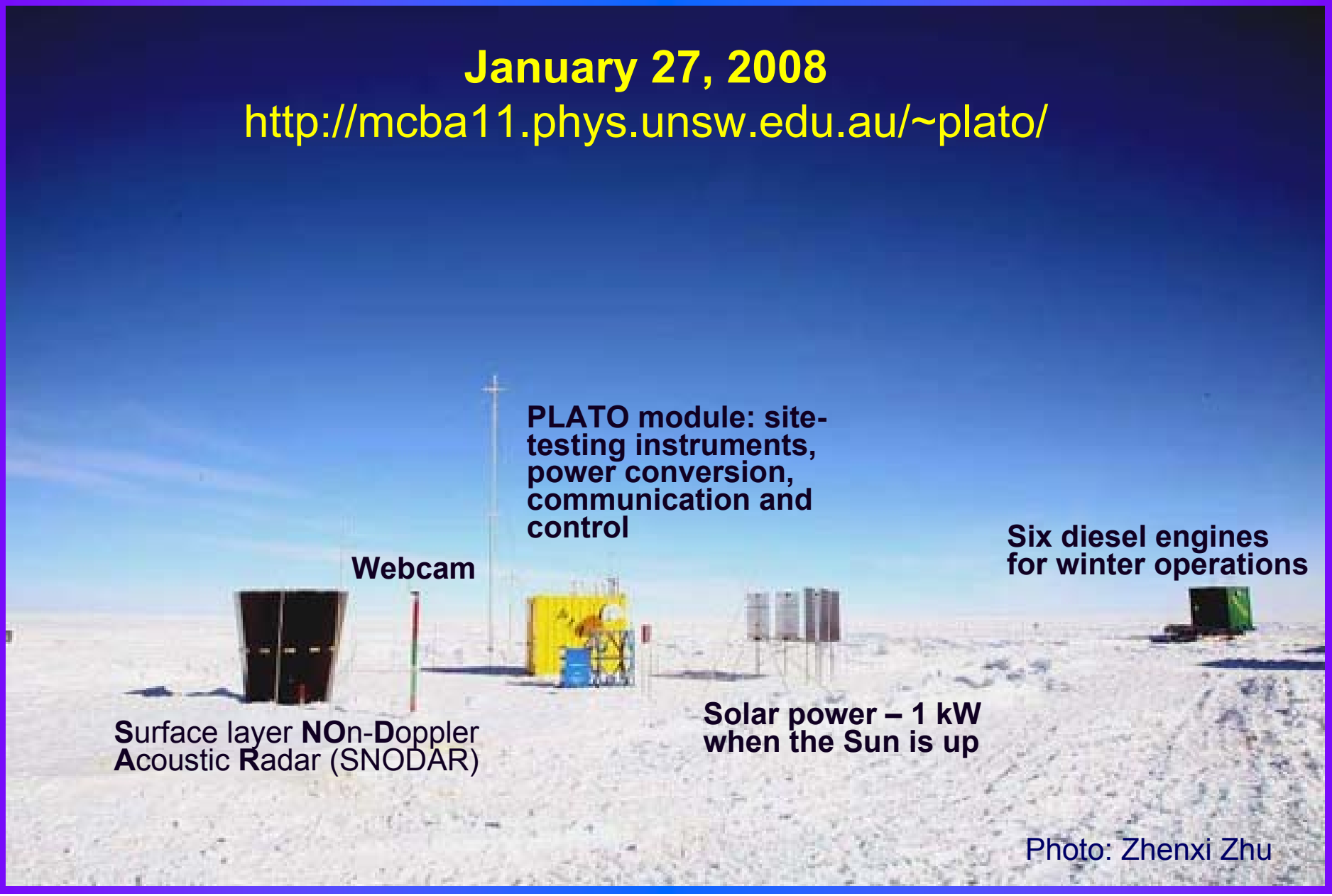
- Fully autonomous module powered by two Stirling engines, deployed by a 1300-km traverse from coastal Chinese station Zhongshan in January 2008
- Worked 205 days - a new record for a remote robotic observatory in Antarctica; upgraded in January to run through 2009

- Chinese Small Telescope Array (CSTAR) is composed of 4 identical telescopes with an aperture 145 mm and a 4.5°×4.5° field-of-view to observe variable stars and measure atmosphere extinction and sky brightness
- Pre-HEAT - a prototype for the High Elevation Antarctic Terahertz submillimeter-wave (660 GHz) telescope to measure transparency of the sky above Dome A
- Surface layer Non-Doppler Acoustic Radar (SNODAR) is designed to measure the height and intensity of the atmospheric boundary layer on the Antarctic plateau

PLATO at Dome A

January 27, 2008

http://mcba11.phys.unsw.edu.au/~plato/



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Long-Duration Ballooning

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McMurdo, Antarctica

August 1988 – first MoA signed

- One LDB launch per two years
- 22 long-duration balloon payloads between 1990 and 2003 (~

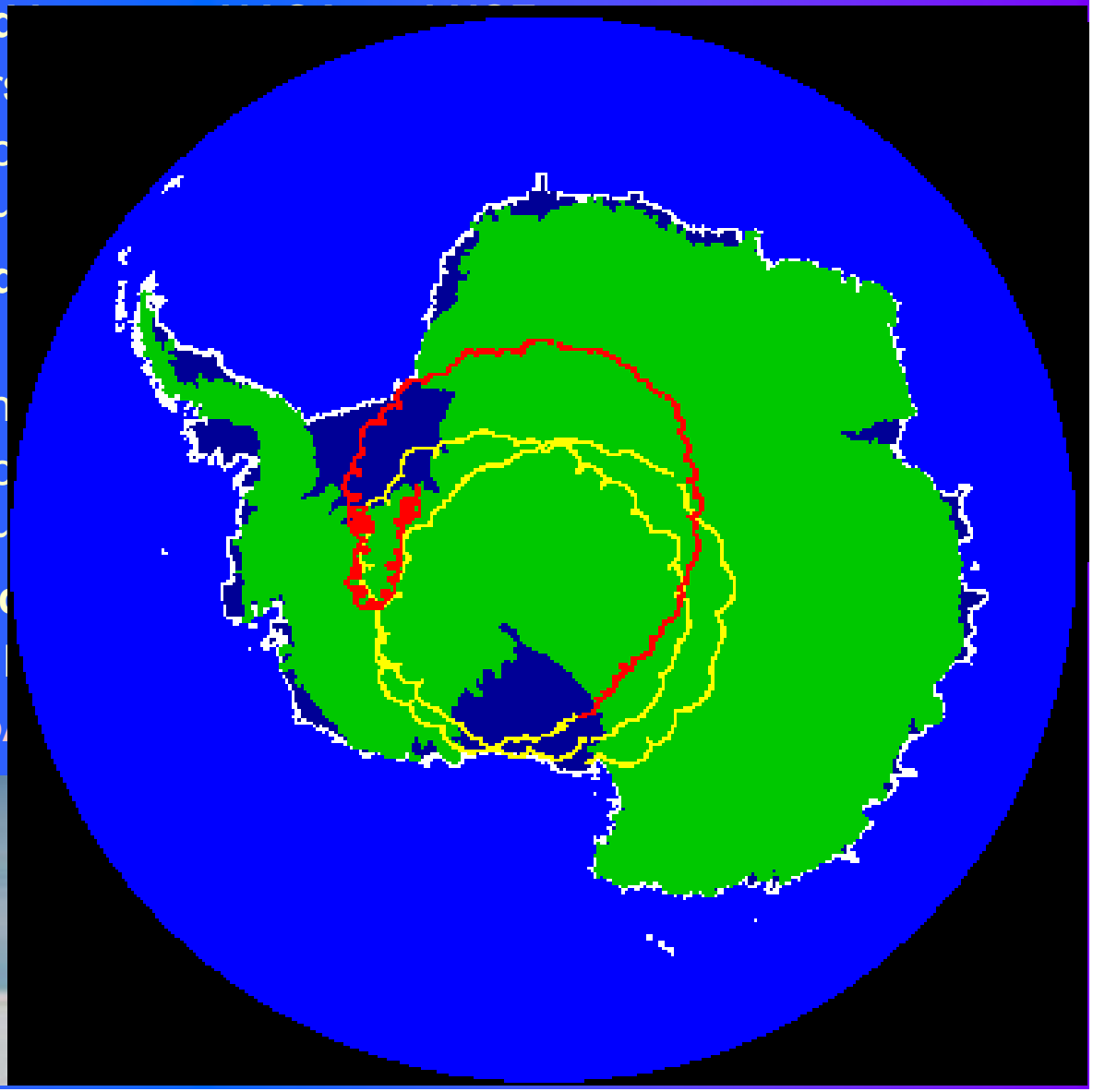
Sep 2003 – second MoA signed (expiring March 31,

- Two launches per years begin
- 15 long-duration balloon payloads between 2003 and 2009 (~

2007/08 and 2008/09 - 3 payloads

Total – 37 payloads funded by

Sep 2008 - Mar 2009 – third Mo



USAP Challenges

South Pole – three *cutting-edge science* astrophysical projects, focused on CMB studies and neutrino physics:

- Require significant logistical support (LC-130 flights, fuel, large teams on the Ice in summer, etc.)
- Need expensive Maintenance & Operations funding as they are long-term projects (BICEP ~6-8 years, SPT ~20 years, IceCube ~30 years)
- Data transmission for these projects requires stable, 24 x 7 communication to South Pole via (slightly offset) geosynchronous satellites
- Current data links to CONUS: NASA retired TDRS F1 satellite (1973; ~6.5 hrs/day) and GOES-3 (~7 hrs/day) – total ~9.5 hrs/day
- NSF upgraded South Pole transmission system in January 2009 to begin using TDRS F4, F5, and F6 satellites (data rate 150 Mbps)

McMurdo – NASA's *highly successful* Long Duration Balloon Program

- Costly logistical support of NASA's LDB launch facility
- Challenging environmental issues with balloons recovery

TDRS Constellation & GOES Locations

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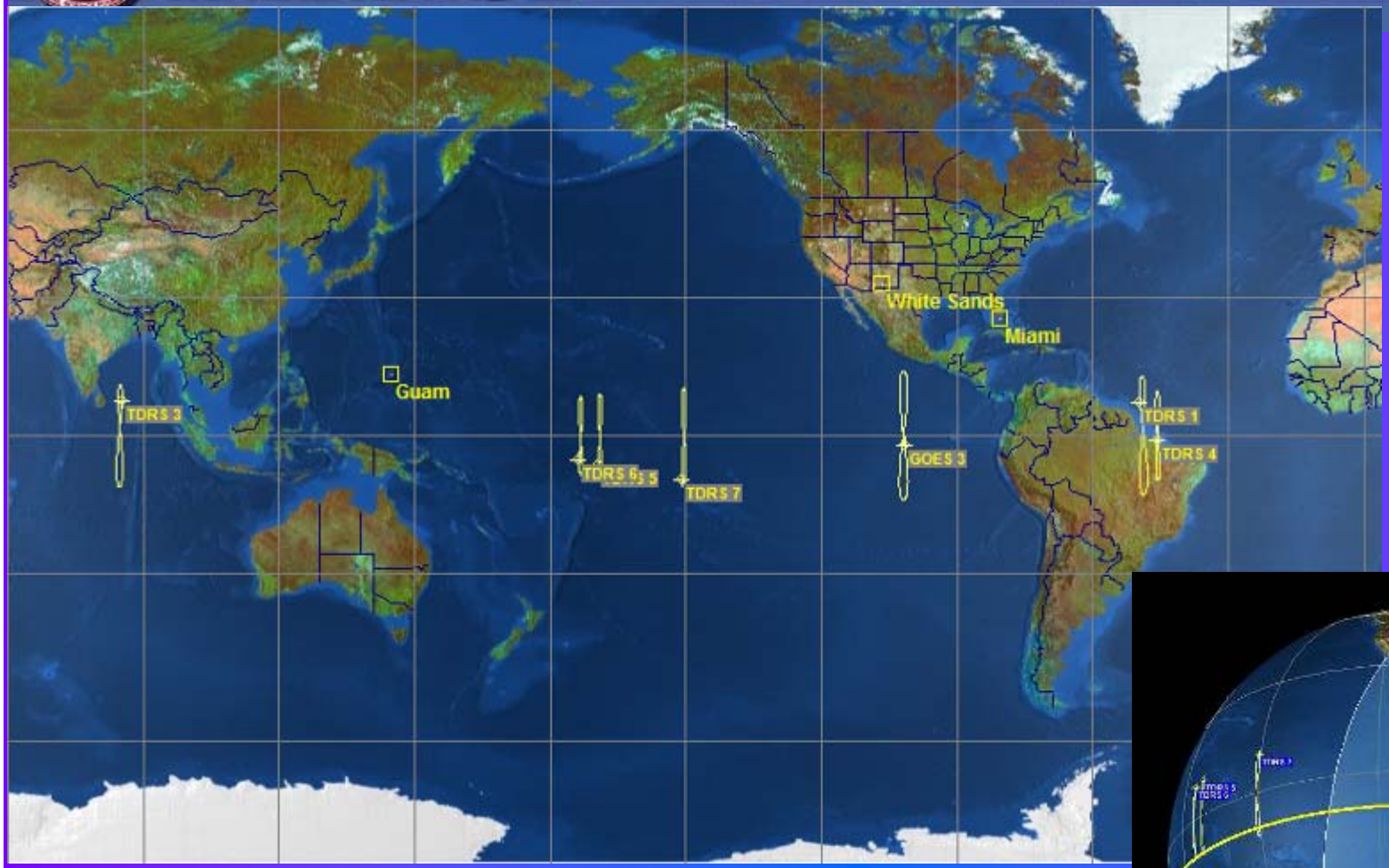

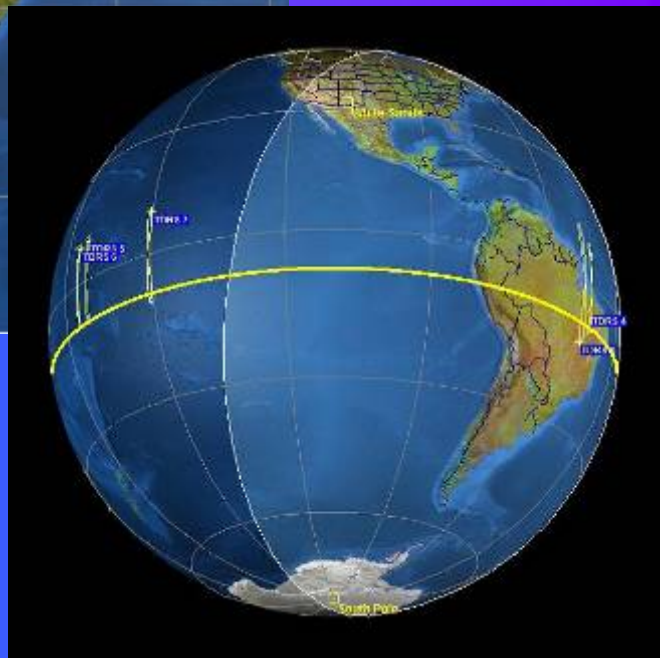

Thank you!

Questions?