Center for Astrophysical Research in Antarctica

An NSF Science and Technology Center
1991 - 2002

John Carlstrom
South Pole Workshop, April 4, 2011
• Brought together three science groups to investigate the potential of the South Pole for astrophysics, to develop new observing capabilities and to use them to conduct unique and cutting edge astrophysics.

  - **Submm astronomy** with AST/RO (Antarctic Submillimeter Telescope and Remote Observatory). Initially at Bell Labs, UIUC, BU, with A. Stark, J. Bally, K.Y. Lo, T. Bania, C. Walker, R. Chamberlin...

  - **Cosmic Microwave Background** initially with Python, led by M. Dragovan and J. Peterson at Princeton

  - **Infrared** led at UChicago by A. Harper, M. Herald, R. Loewenstein and company, collaborators at GSFC, NOAO, and elsewhere.
in the beginning...

• Attracted by the promise of exceptional atmospheric transmission, low background (especially in the near infrared) and the long nights. Build on pioneering work of Martin Pomerantz.

(stayed for the exceptional low sky noise at long wavelengths in the mm/submm and the enormous 24/7/52 throughput enabled by the atmospheric conditions and the unique geographical location, i.e., sources never set. “relentless observing”)
Gamma Rays, X-Rays and Ultraviolet Light blocked by the upper atmosphere (best observed from space).

Visible Light observable from Earth, with some atmospheric distortion.

Most of the Infrared spectrum absorbed by atmospheric gasses (best observed from space).

Radio Waves observable from Earth.

Long-wavelength Radio Waves blocked.

Courtesy NASA Spitzer website
• Started rigorous site testing
  - Teamed up with Australians, especially John Storey and collaborators at JACARA (Australian Centre for Astrophysical Research in Antarctica)
  - Rigorous Optical/Infrared testing: “seeing,” opacity, cloud coverage (see M. Burton’s talk), see also http://www.phys.unsw.edu.au/jacara/AASTO/index.php
in the beginning...

• Started tradition of strong Education and Outreach:
  - Outreach directors: Jim Sweitzer to 1997, then Randy Landsberg
  - High school teachers and students to the Pole...
  - Successful and long lasting immersion program for inner city high school kids, “Space Explorers.” KICP continues it to this day.
in the beginning...

• Learned
  - How to operate telescopes (and how not to power an AASTO)
  - How to work together with limited resources (including AMANDA)
  - How to work effectively with NSF and its contractor(s)
  - About the atmospheric conditions

• CARA Directors
  - 1997 - 1999: Meyer / Carlstrom
  - 1999 - 2002: Carlstrom / Meyer
Snapshot of CARA and South Pole Astrophysics from NSF site visit 1999
- Python CMB on tower
- AST/RO submm with now standard warm access supported on separate foundation. First successful winter observations.
- AST/RO 1.7m submm telescope. MAPO and SPIREX in the background.
- MAPO at dawn
SPIREX 60cm infrared telescope with baby-bonnet dome and Al Fowler (NOAO)
- CARA & Australian JACARA supported AASTO site testing (first in a long series of autonomous site testing modules).
- Shared resources: MAPO model machine shop and Bob Spotz (continues with SCOARA)
What had been accomplished

• Modern Lab and observatory building
  - Participated in the design of MAPO and DSL (DSL was in the works)
  - Data transmission bandwidth (Rob Loewenstein, Pat Smith)

• Shared resources:
  - Model machine shop & electronics shop
  - Shared vacuum, RF, test equipment
  - Coordination with AMANDA
  - Liquid helium supply (was always an issue)

• Telescopes operating through the winter
• Astrophysical results
• Full characterization of the atmospheric conditions.
- Python V map and power spectrum (black points, Coble et al, 1999) along with first Viper results (red, Glanz Science Jan 1999, Peterson et al. ApJ, 2000). This was pre-Boomerang, Maxima and DASI.
- SPARO on Viper (Submm Polarimeter for Antarctic Remote Observations) 450 um observations of the dust polarization over a *large area* of the Galactic Center. SPARO discovered that the magnetic field in the molecular gas at the Galactic center is toroidal, in sharp contrast to the poloidal field exhibited by the energetic, non-thermal GC filaments. Novak et al., ApJ, 2003.
- AST/RO large area maps of the submm tracers of hot dense gas in the Galaxy. Shown is the inner 3 degrees of the Galactic Center region in CI, CO 7-6 and CO 4-3 with comparisons of the mm transitions of CO 1-0 and CS 2-1. Martin et al., ApJS, 2004.
SPIREX

- $\lambda = 3.5$ um image of NGC6334 from SPIREX 60cm telescope at South Pole reveal photodissociation regions around hot young dust enshrouded stars.
Site testing

• Characterization of the site:
  - South Pole was the best characterized IR site in the world. Good, but not as good as hoped. Atmospheric lines limited improvement in the near-IR sky emission. Boundary layer led to poor intrinsic seeing.
  - Millimeter and submillimeter atmospheric conditions excellent.
Infrared Sky Background

Near-IR effectively 10-20 times lower than good temperate sites, between the lines. Mid-IR about 2 times better.


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Slide adapted from Burton/Storey
But high resolution “seeing” only above a ground-level turbulent layer layer

Low altitude of the atmospheric turbulence leads to easy adaptive optics. I.e., tip-tilt or place telescope on very high tower.

Height where the residual boundary layer seeing is 0.1” or better 50% of the time.

Slide adapted from Burton/Storey

Dome C: Agabi et al., PASP, 2005

Swain and Gallee, 2006
Exceptionally dry

Lane 1998, ASP Conf 141, 289
See also Chamberlin et al., 2001
mm/submm atmospheric transmission

- MIDDLE and BOTTOM: Contributions of the dry air and water vapor opacity terms.

H$_2$O component dominates the "sky noise"
Superb mm/submm atms stability

- **BIG BONUS:** Incredibly stable atmosphere at mm/submm wavelengths! More than an order of magnitude better than any other developed site. Perfect for carrying out large area surveys, especially of extended low-brightness emission, e.g., CMB. See Lay & Halverson 2000 and Bussmann et al. 2005
planning the future in 1999

“The combined results indicate that the South Pole is the best ground based site known for projects requiring imaging over large angular scales, large area surveys, or extremely high sensitivity at thermal infrared through millimeter wavelengths”

• Exploit most unique strength of the site
  ➔ mm/submm large surveys, especially of extended, low-brightness emission.

• Highest scientific impact
  ➔ Cosmic Microwave Background push DASI & ACBAR on Viper.
Nov - Dec 1999

Installing DASI (including: Carlstrom, Dragovan, Halverson, Holzapfel, Kovac, Leitch, Pryke, ...
Nov 2000: ACBAR on rebuilt VIPER

Installing ACBAR (including Bock, Holzapfel, Kuo, Lange, Peterson, Reichardt, Ruhl, Runyan,...)
• I think it was a good decision...
Scientists Hear the Tiny Hum They Say Ignited the Big Bang

By JANE GELIAK
WASHINGTON April 30 — The...
I think it was a good decision...
\[ \frac{1}{l(l+1)} C_l^{TT/(2\pi)} [\mu K^2] \]

Multipole Moment \((l)\)

South Pole Instruments

ACBAR
QUaD

WMAP 7yr
I think it was a good decision...
I think it was a good decision...
• that’s all. Thanks.