Antarctic astronomy

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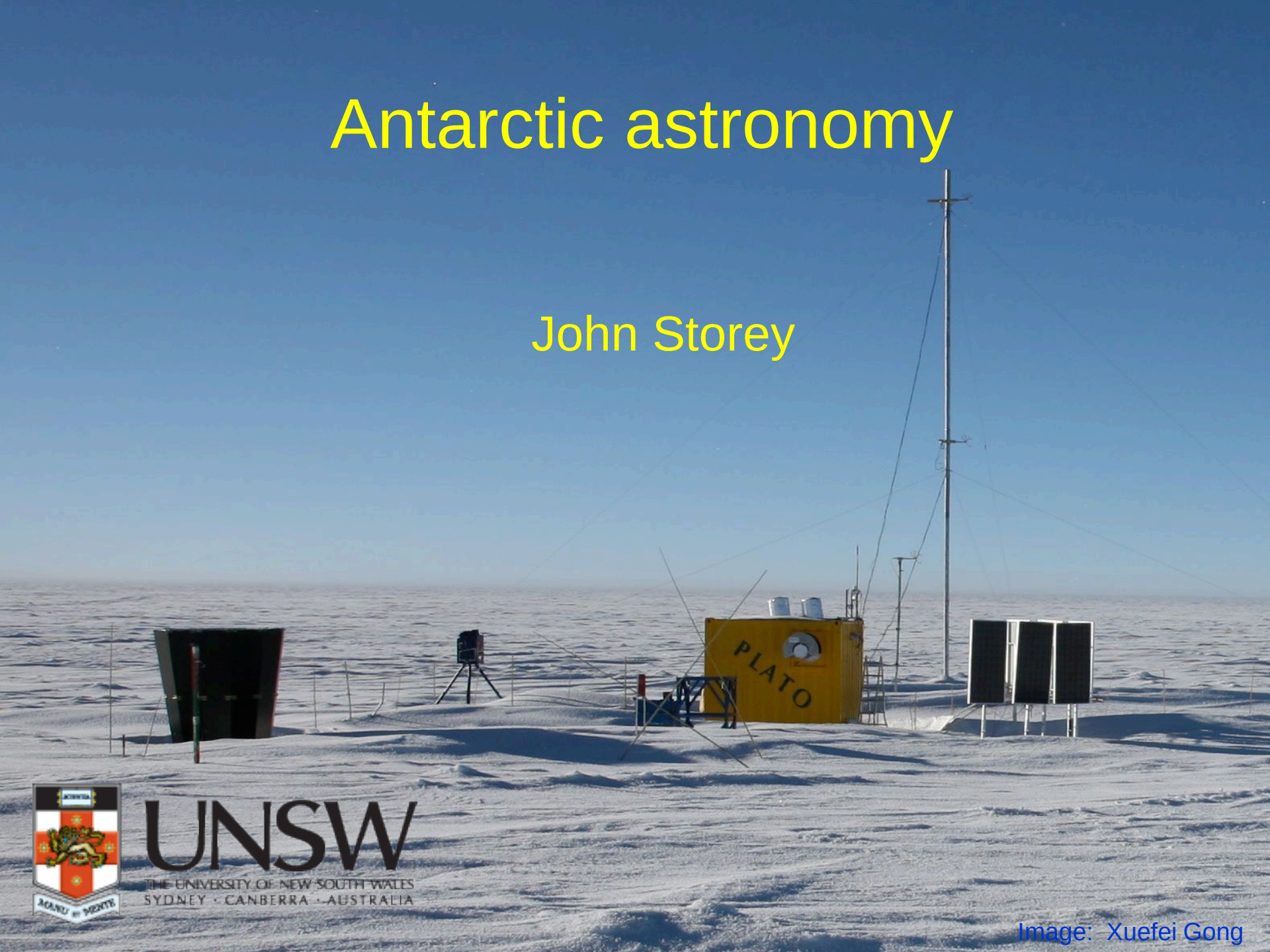


Image: Xuefei Gong

Outline

- Why Antarctica
- Site testing
- PLATO
- The stations
- New projects

Image: Daniel Luong-van

Why Antarctica — a few good reasons

Relative to the *best* temperate sites:

- The infrared sky is 20 ~ 50 times darker
- The water vapour content is ~10 times lower
- The free-atmosphere seeing is ~2 times better
- The coherence volume is ~10 times greater
- Scintillation noise is ~2.5 times less
- The atmospheric boundary layer is only 10 ~ 20 metres high
- The aerosol content is ~50 times lower
- The sky is continuously dark for months

Why Antarctica — a few more good reasons

For the unconventional astronomer:

- There's lots of ice
- The circumpolar vortex invites long-duration ballooning
- Antarctica is the only place on earth set aside for science by international treaty
- Antarctica is beautiful

Image: Daniel Luong-van

What isn't there to like?

Not much, really…

- It's cold – get over it!
- Longer twilight
- Less sky coverage
- Accessibility is less than ideal
- The relative humidity is high (icing problems)
- The temperature in the boundary layer is unstable

Image: Karim Agabi

Deployment to Antarctica is one thousand times cheaper than space

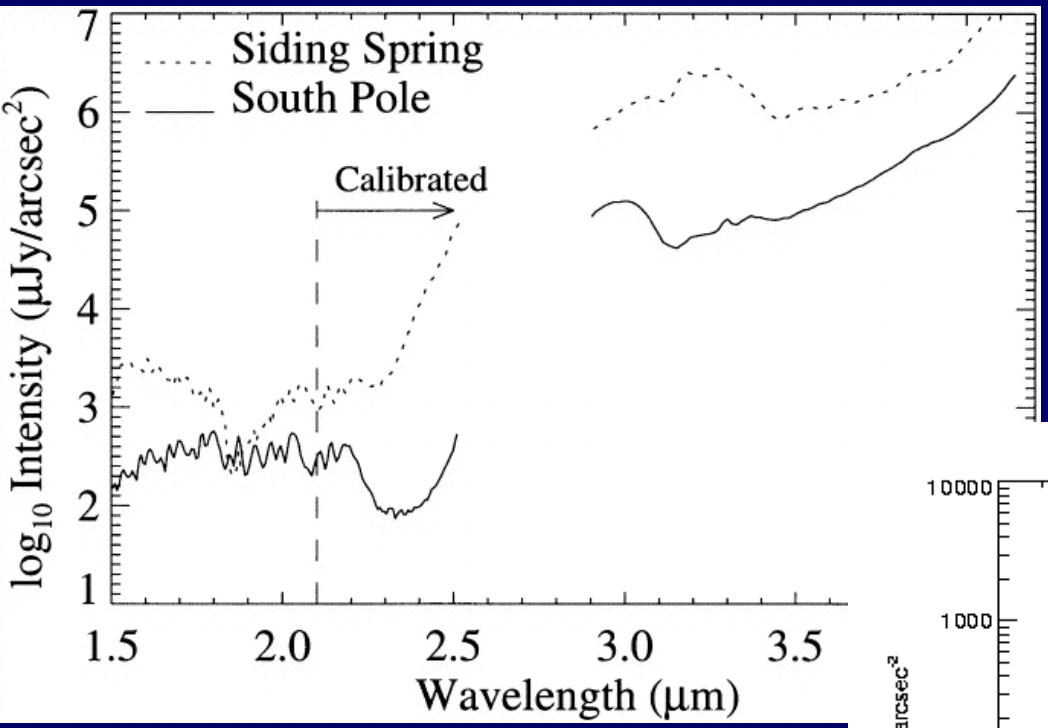
($10/kg *versus* $10,000/kg)

Image: John Storey

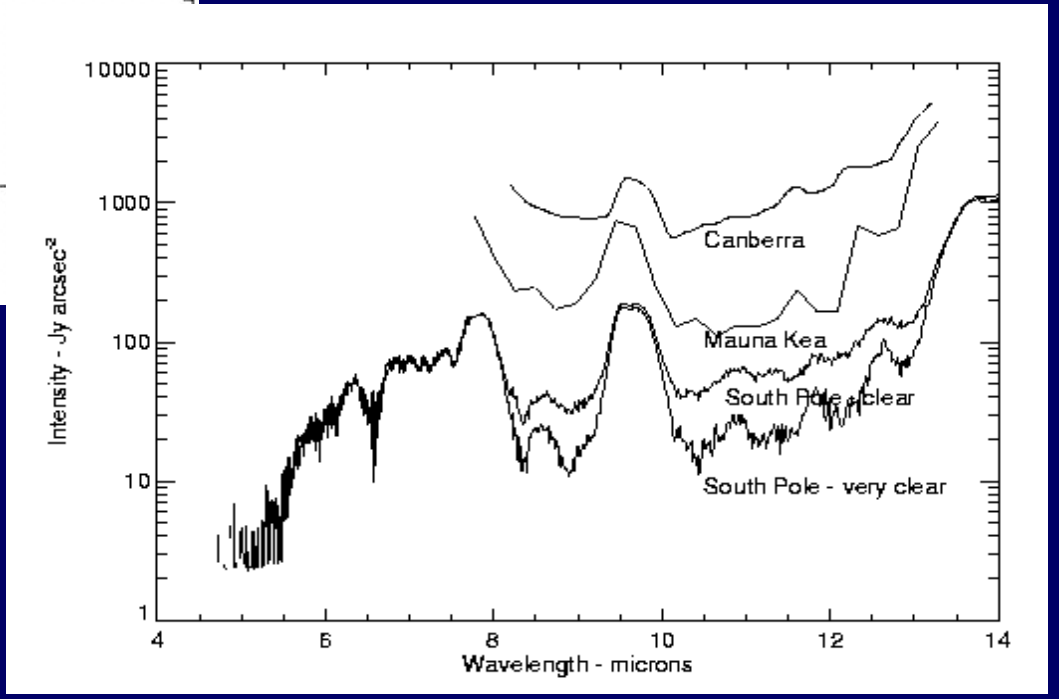
Image: ESA

IR sky brightness

Site comparison



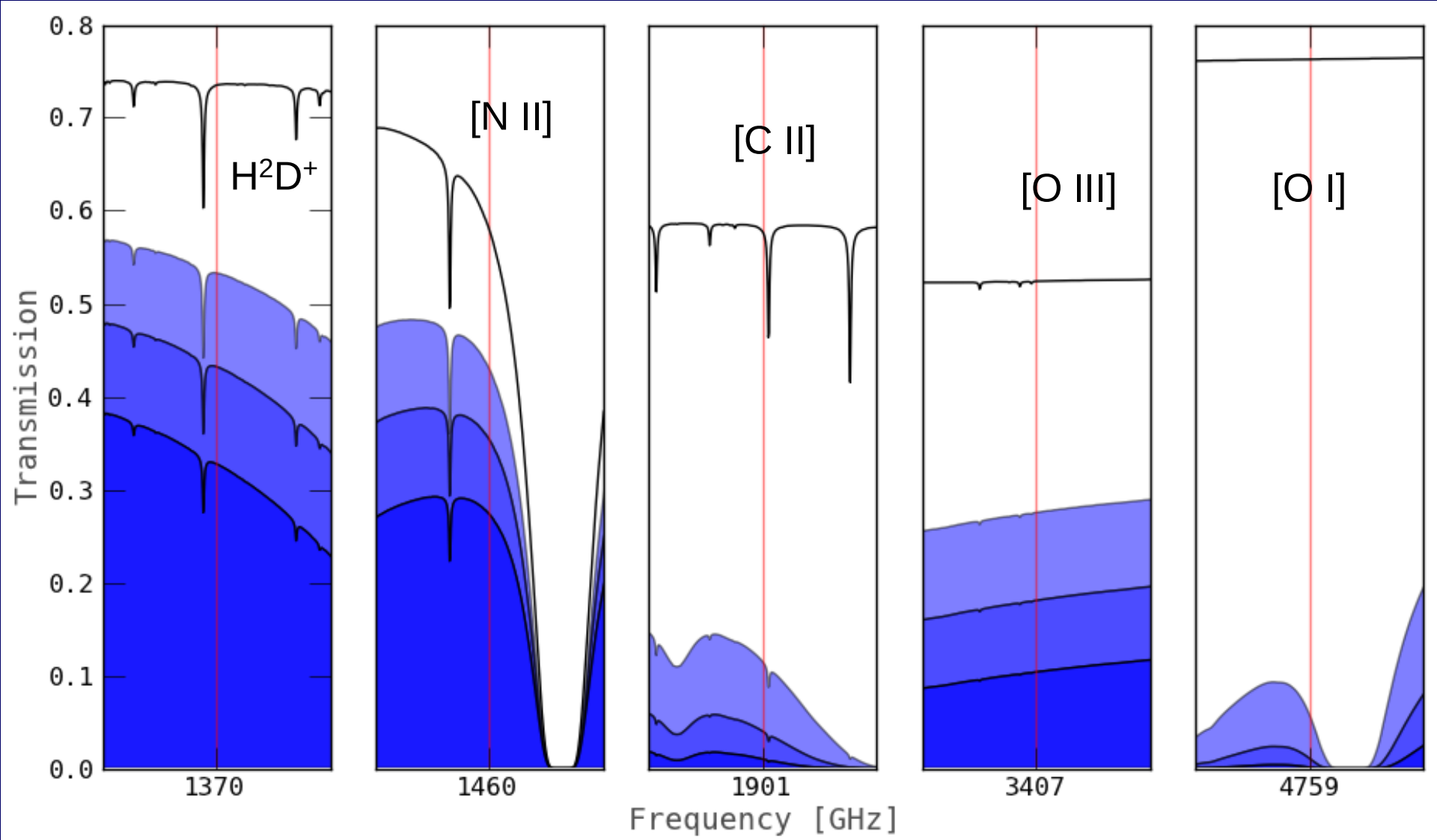
Near-infrared



Mid-infrared

Phillips et al 1999

Chamberlain et al 2000

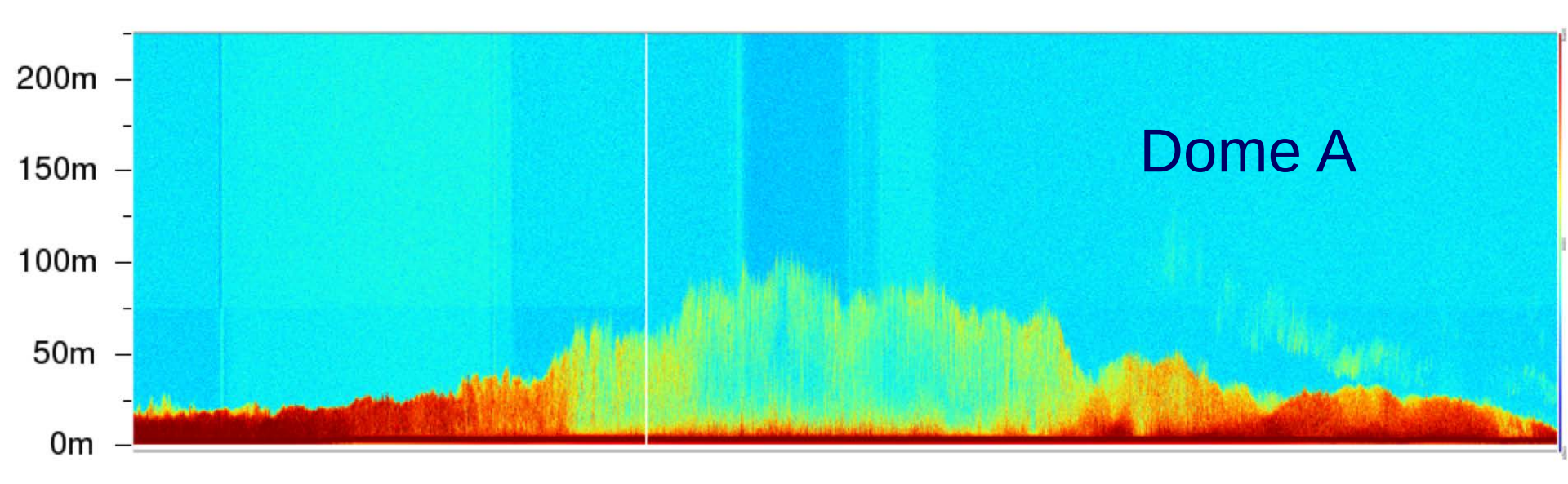


Ridge A. Top to bottom: dry-air only, best 10 percentile, best 25 percentile, median winter transmission.

Sims et al., 2012

Stable planetary boundary layer

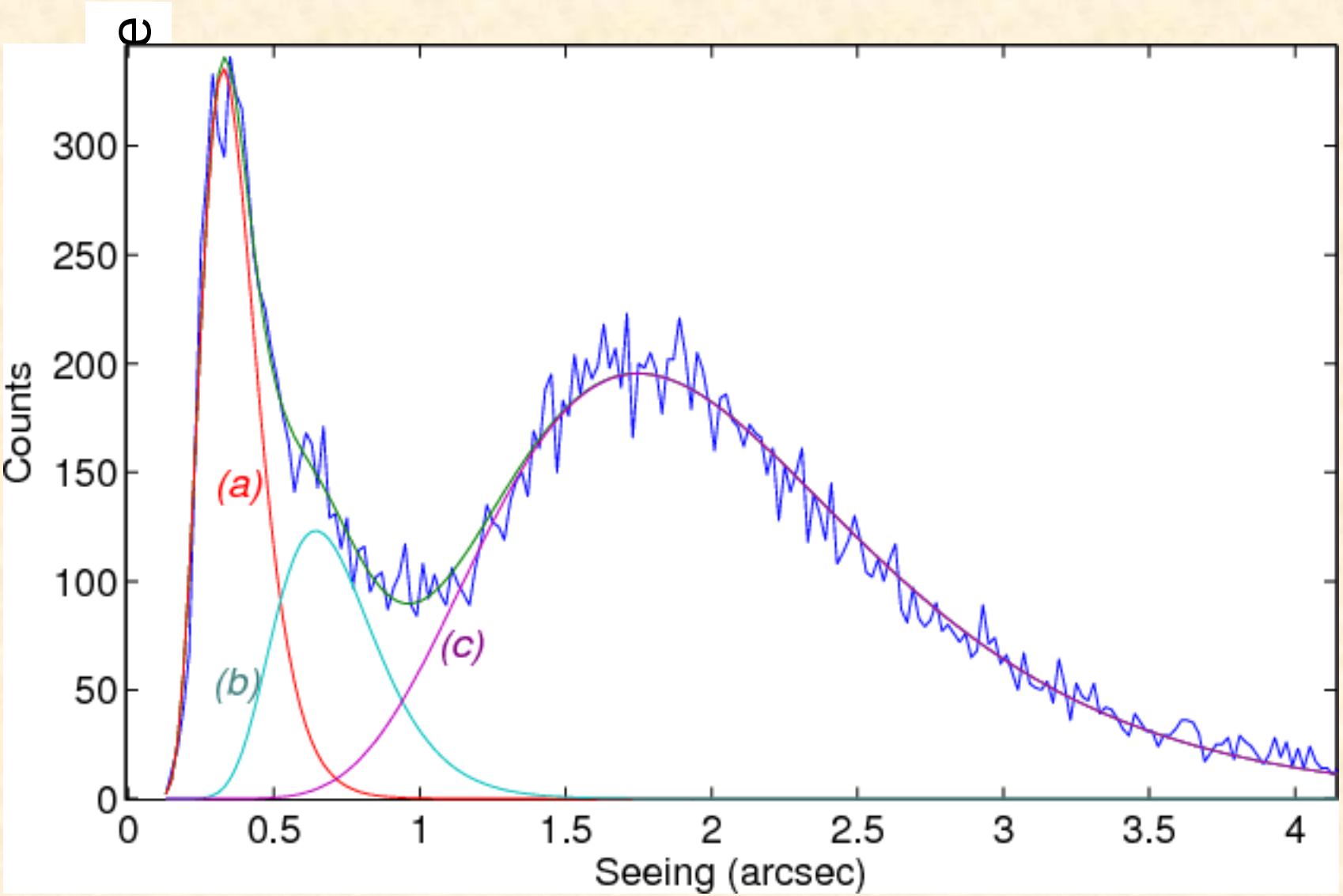
- The temperature inversion is huge (often 5ºC/metre)
- The Stable Boundary Layer is thin (~ 25 metres)
- As a result, the Stable Boundary Layer is *stable*



24 hours

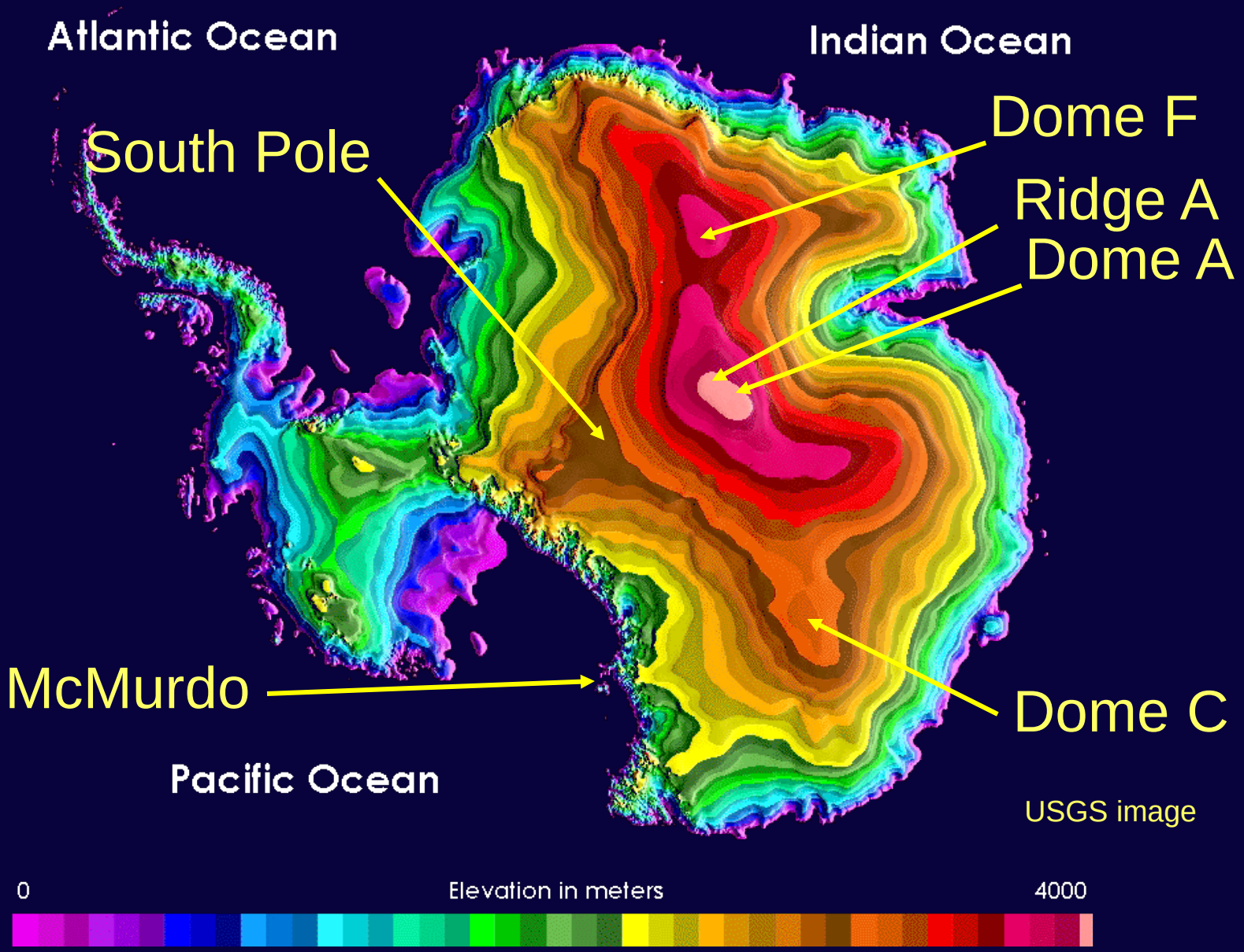
Image: Bonner et al 2010

Dome C



Aristidi et al (2009)

Contour map of Antarctica



South Pole

Station owner	USA
Completion date	1957
Geostationary satellites visible	No
Advantages	Constant ZD sources
Disadvantages	Cloud cover Thick boundary layer Low elevation

Amundsen-Scott station, South Pole

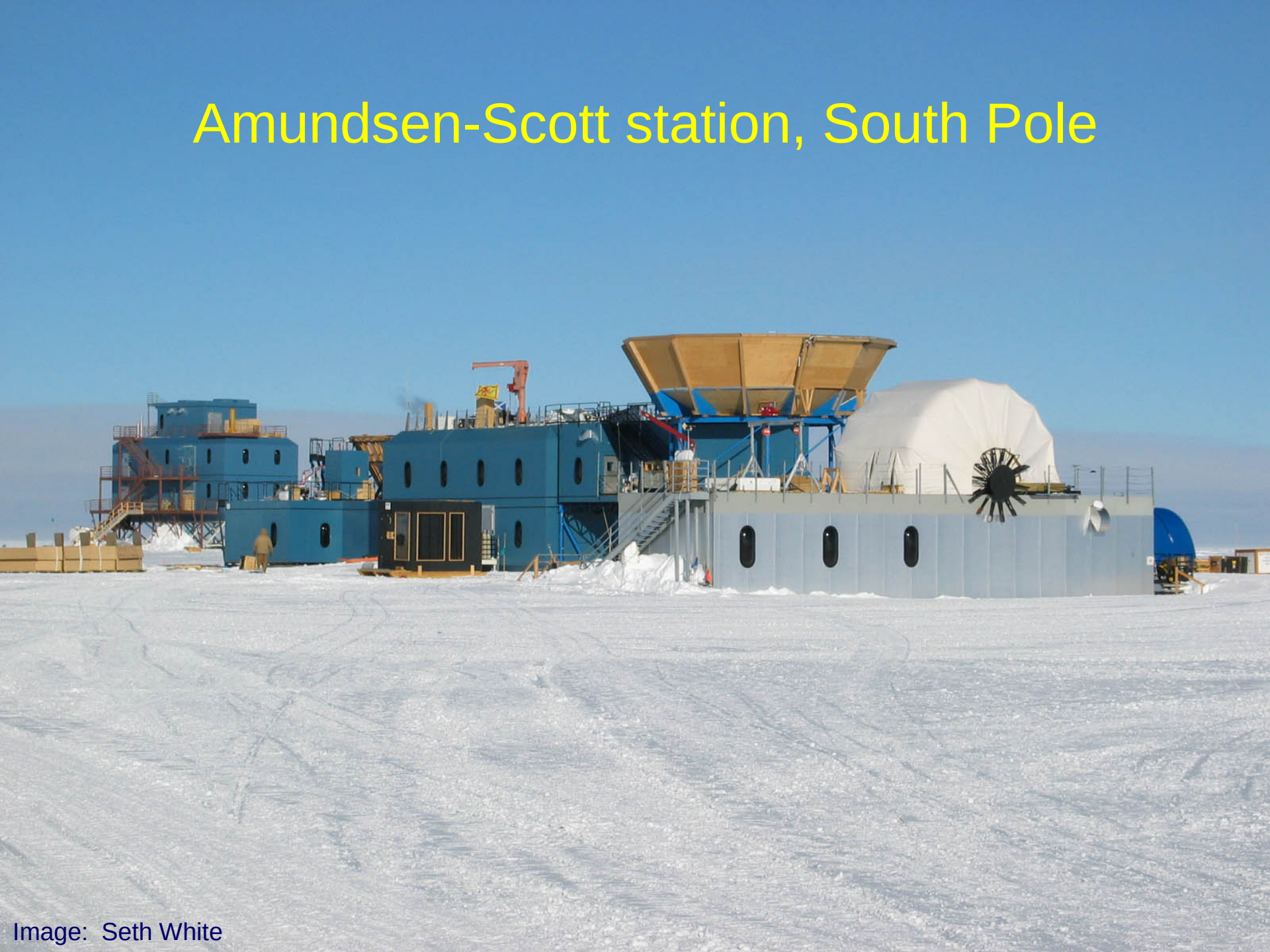


Image: Seth White

The South Pole Telescope shows that major astronomical facilities are possible in Antarctica

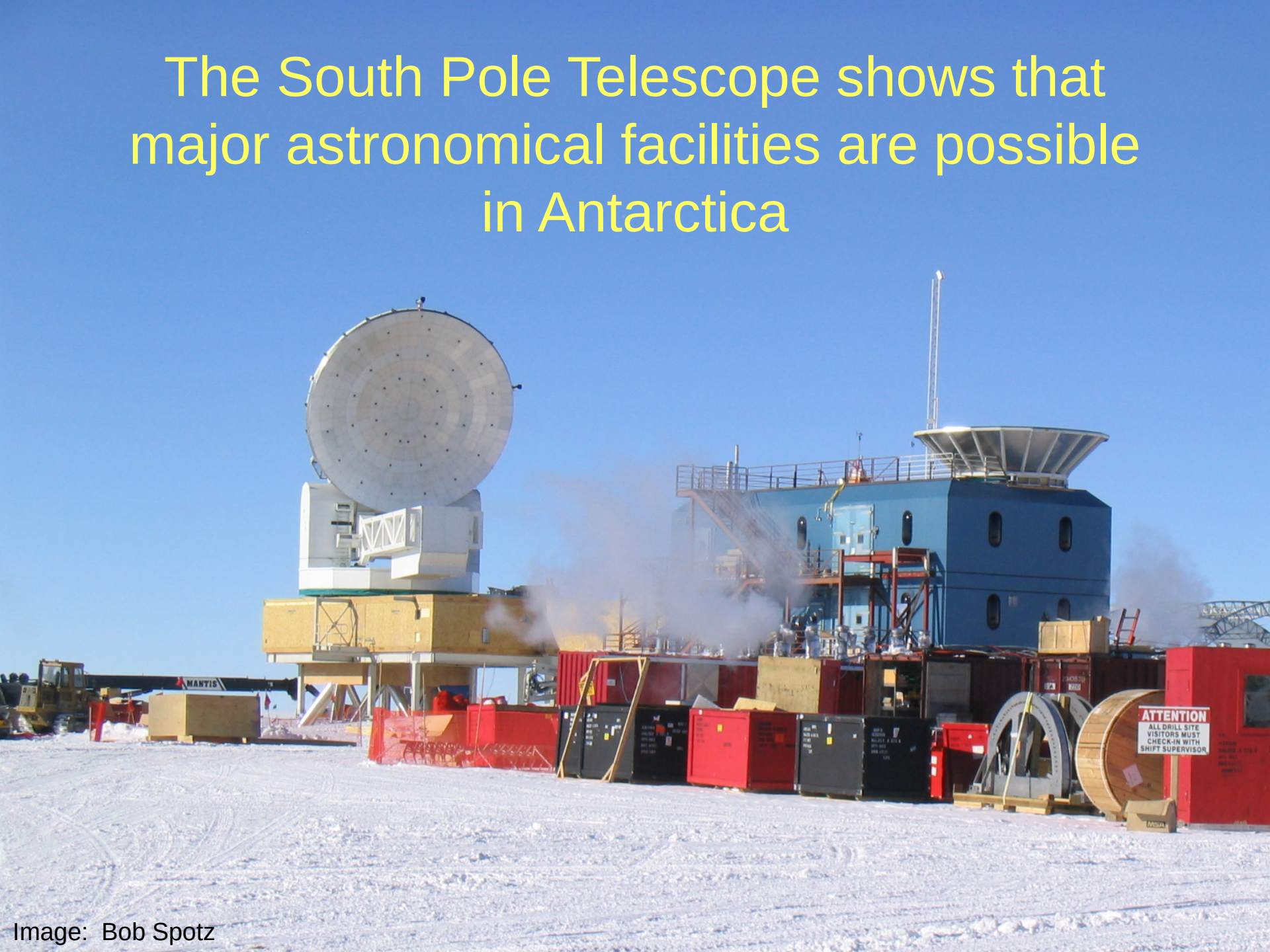
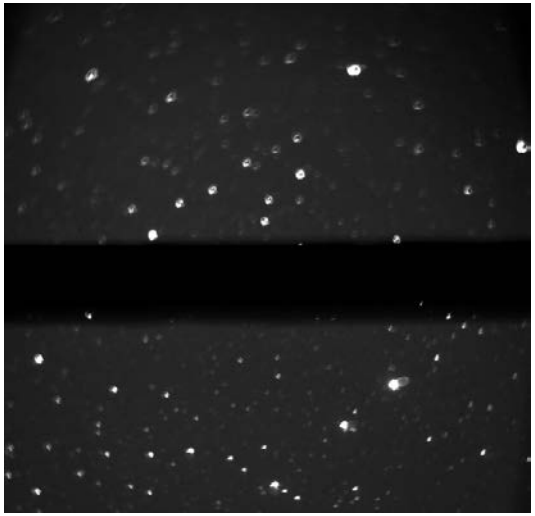


Image: Bob Spotz

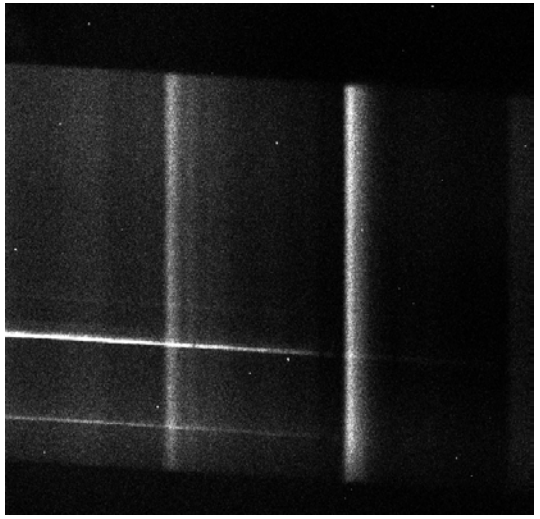
Gattini at South Pole

UV experiment with 6-inch aperture telescope
feeding 4^{o} FOV imager and 2^{o} long slit spectrograph

Installed on MAPO roof in Jan 2011



Bessel U image
(sloan g' and "super-U" complete filter set)



350nm-450nm x 2^{o} spectrum

SPIE 8444-62 "The Gattini South Pole UV Experiment"

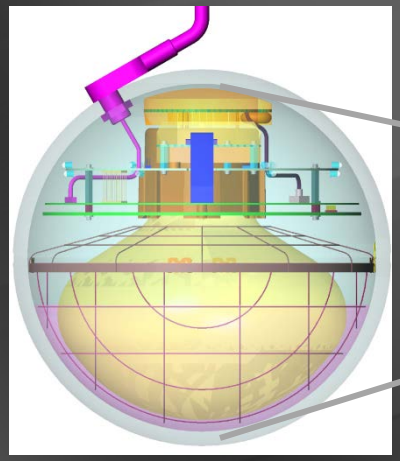
Moore et al

These folk are astronomers, too.

Image: http://icecube.wisc.edu

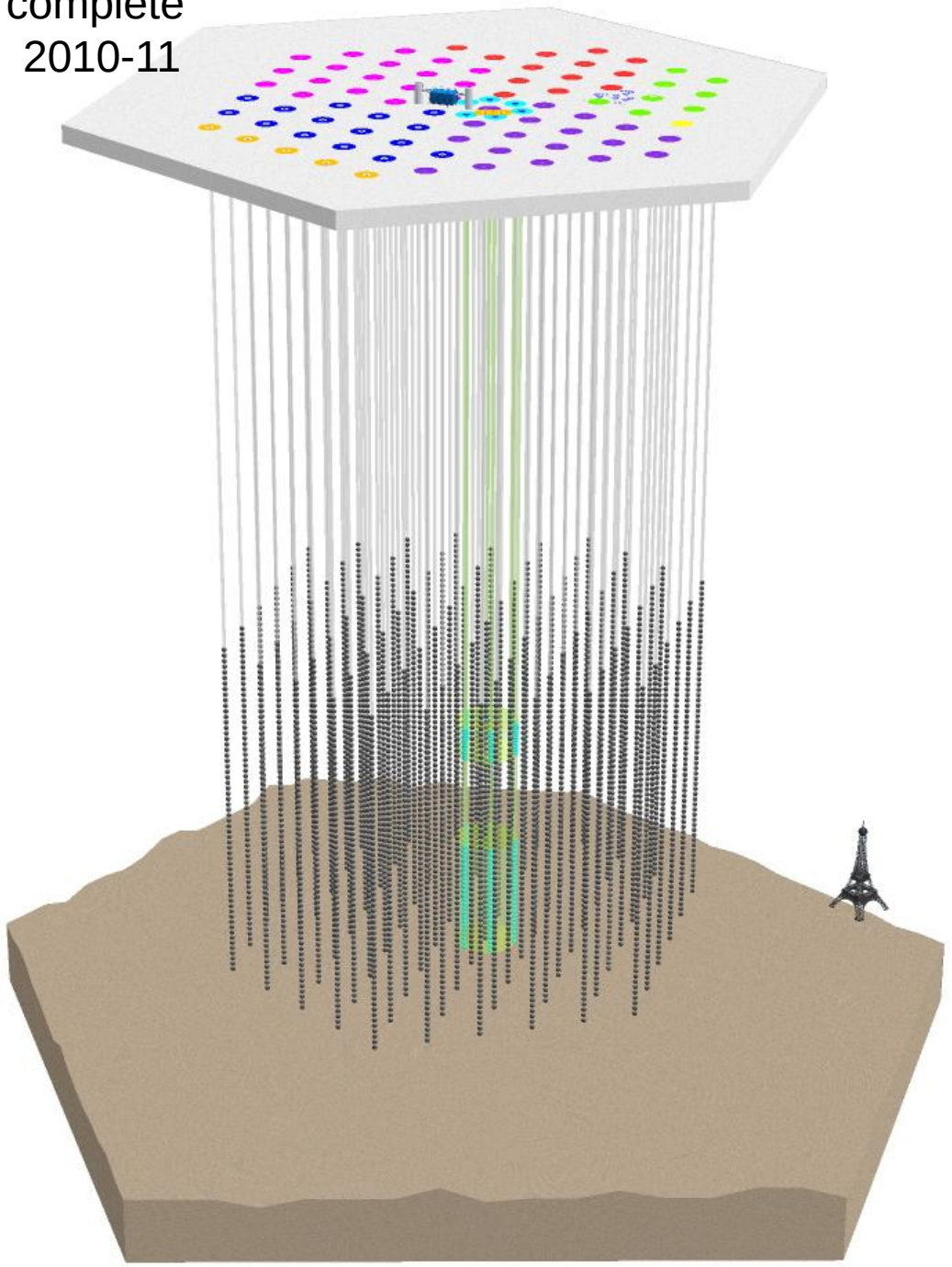
IceCube / Deep Core

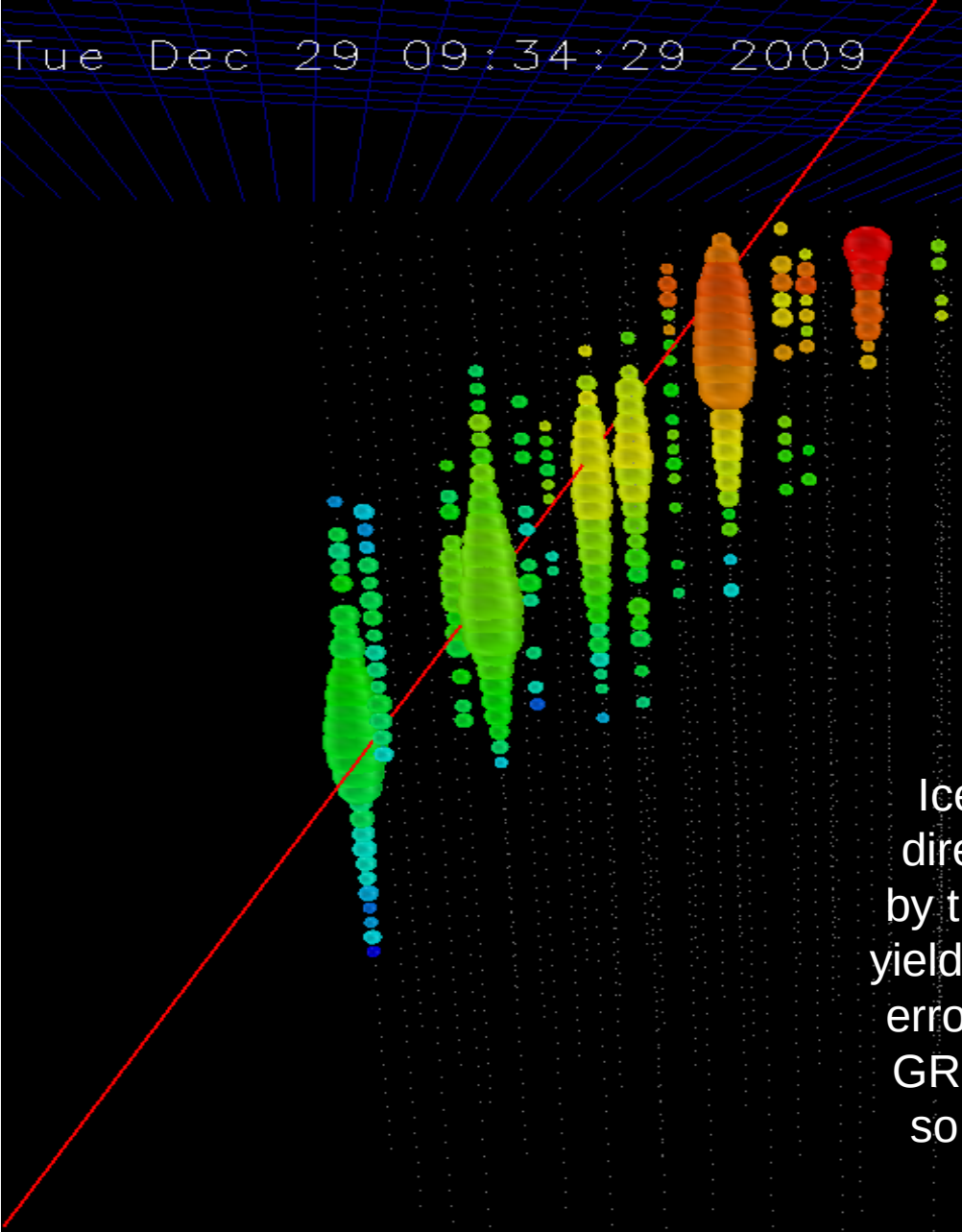
- 5320 optical modules on 86 strings (+ IceTop)
- detects ~220 neutrinos and 3×10^8 muons per day
- threshold 10 GeV
- angular resolution
  ~ 0.5 degree



Digital Optical Module (DOM)

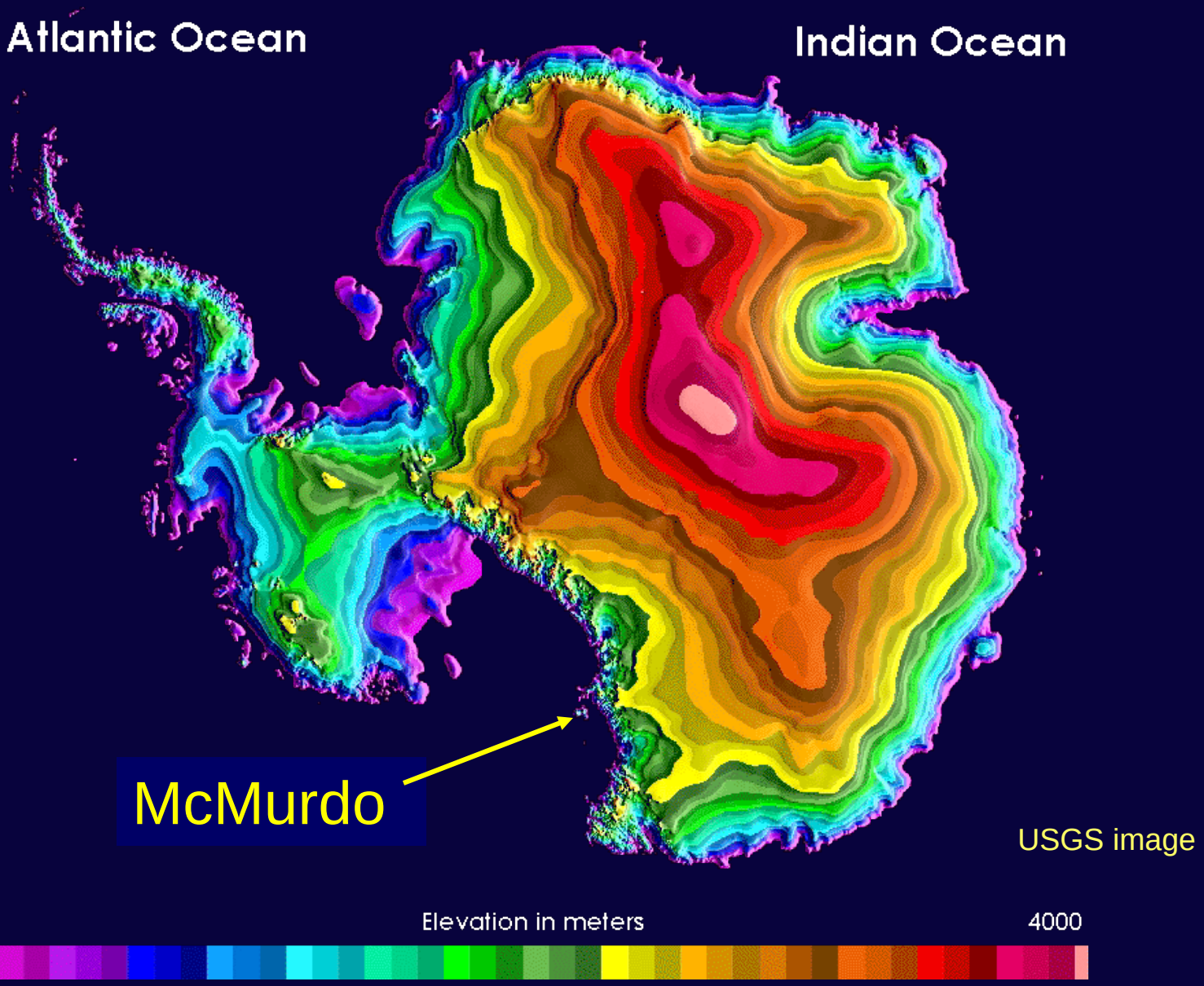
complete
2010-11





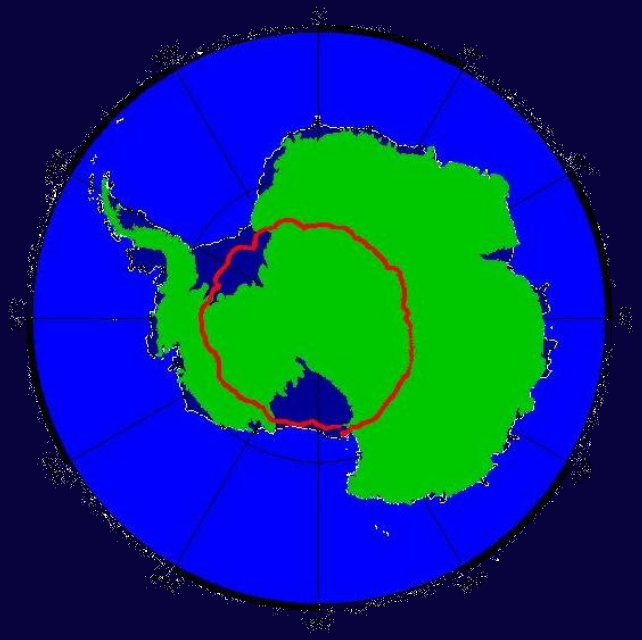
Icecube event within 0.2 degree of the direction of a gamma ray burst observed by the SWIFT satellite. The reconstruction yields an energy of 109 TeV and an angular error of 0.2 degree. Although it misses the GRB time by 14 hours, the background is so low that this was the most significant candidate.

Contour map of Antarctica

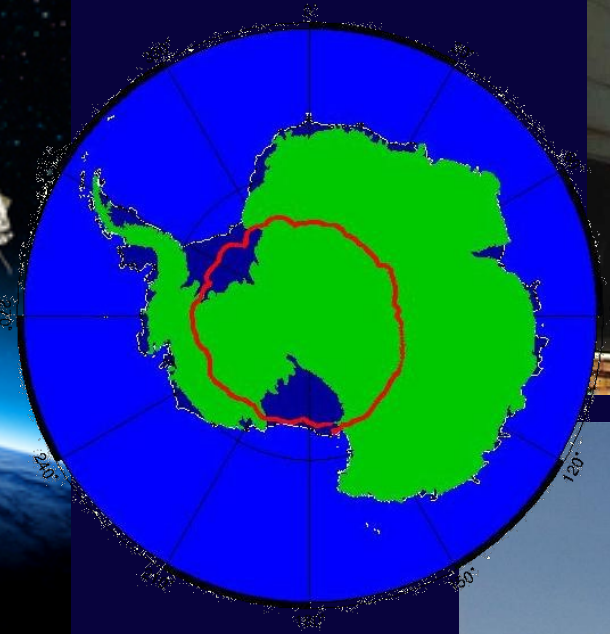


McMurdo

Station owner	USA
Completion date	1957
Geostationary satellites visible	Easily
Advantages	Long-duration balloons
Disadvantages	Useless for anything else

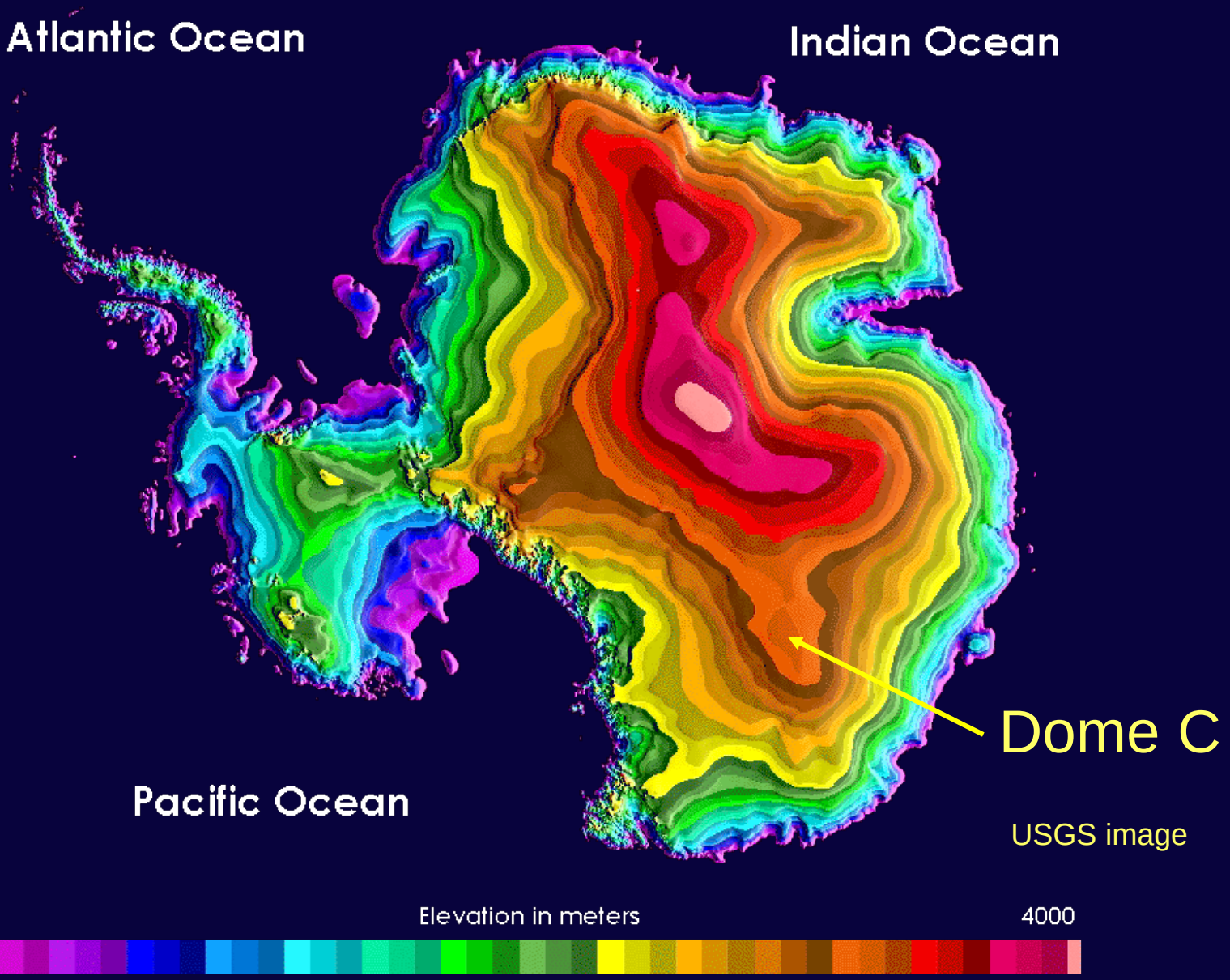


McMurdo



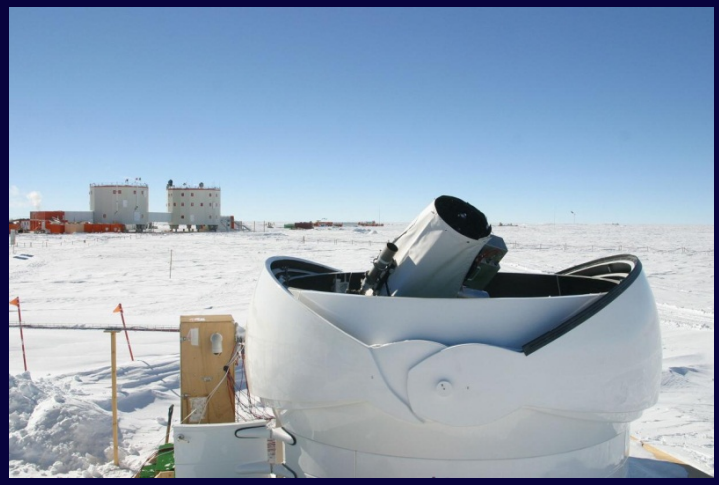
Images: McMurdo balloon-launch facility

Contour map of Antarctica



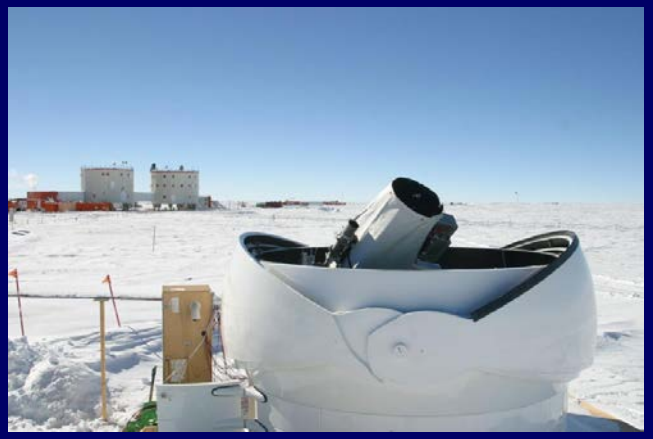
Dome C

Station owner	France/Italy
Completion date	2005
Geostationary satellites visible	Yes, but…
Advantages	Minimal cloud cover Thin boundary layer
Disadvantages	Rapid temperature variations

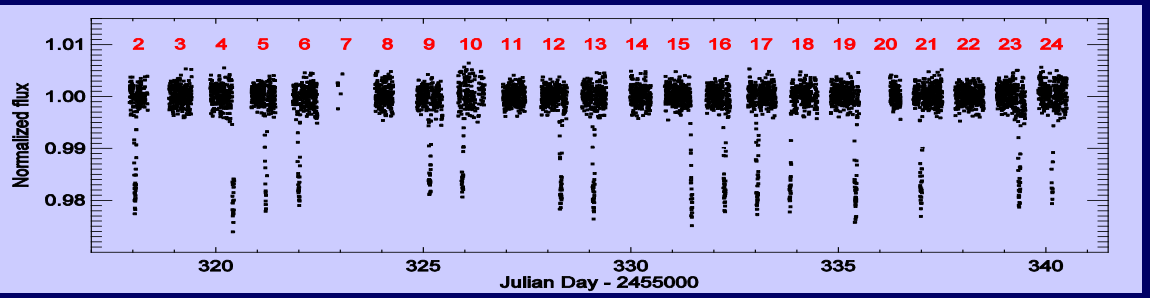


ASTEP-400

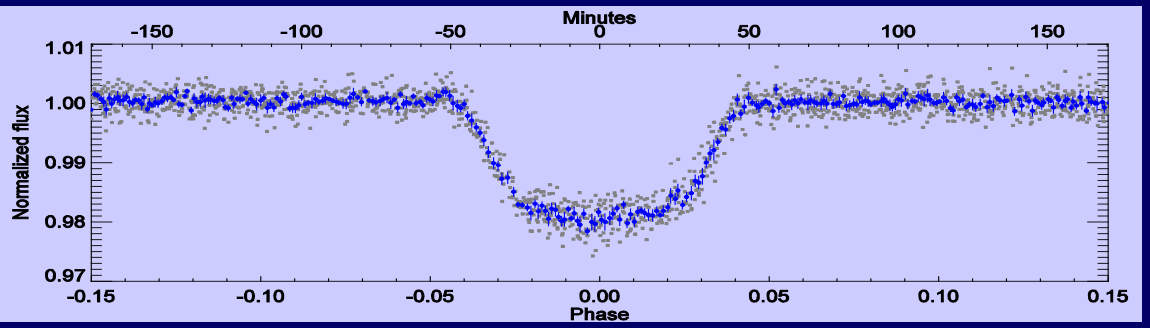
- Goals: - transiting exoplanet discovery
  - follow-up of known transits.
- Photometric accuracy (3 mmag unbinned, <0.5mmag binned)
- ~10 exoplanetary candidates found (follow-up in progress).



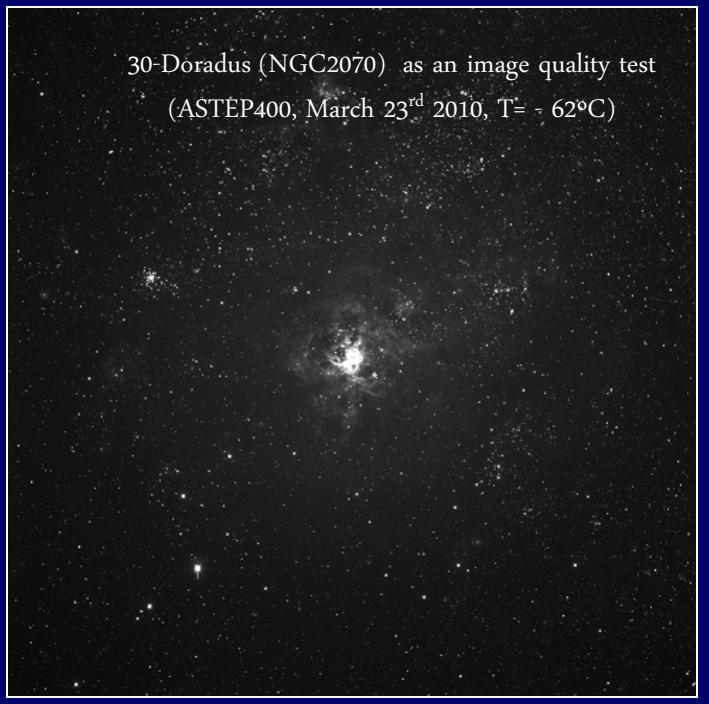
The ASTEP400 telescope



WASP19b lightcurve (2010). Estimated stellar variability has been subtracted.



WASP19b primary transit (black: unbinned, blue: binned)



PLATO (Plateau Observatory) is a complete observatory that provides power, thermal management and communications

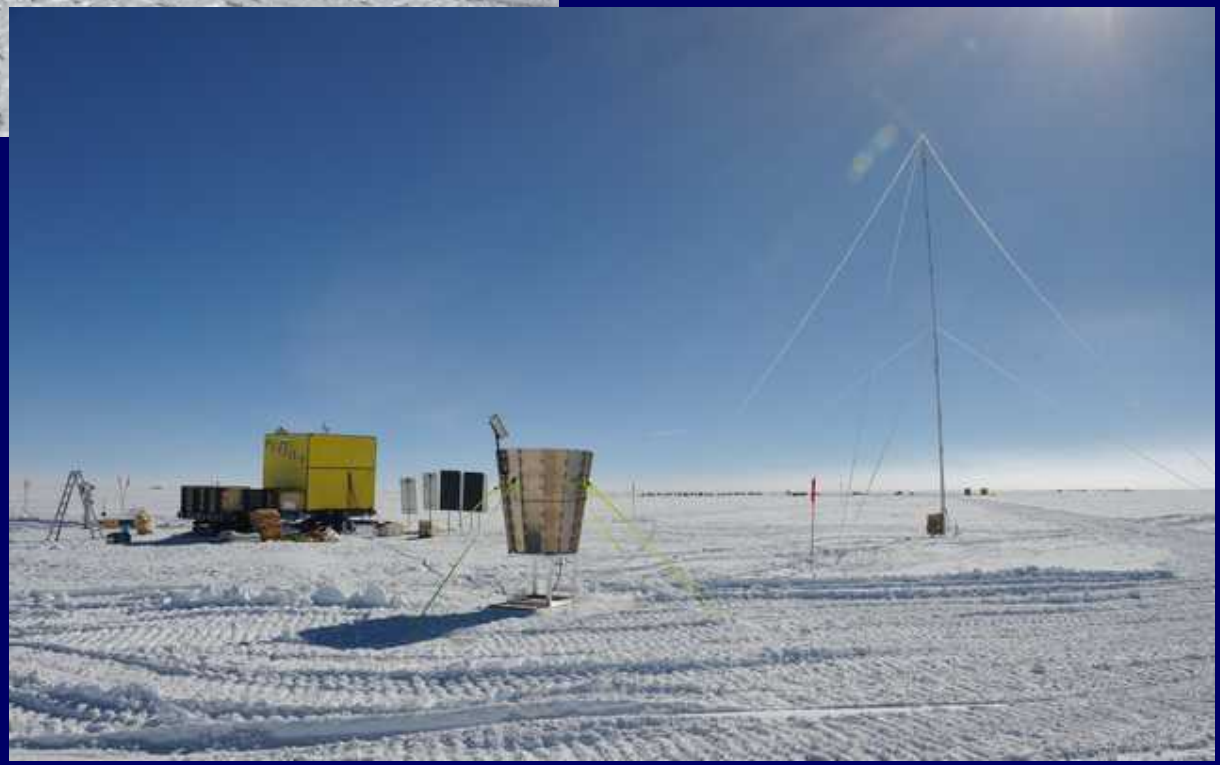
Image: Michael Ashley

QuickTime™ and a
decompressor
are needed to see this picture.

PLATO-F unloaded from *Shirase*

Image: Hirofumi Okita

PLATO-F, at Dome F



Images: Hirofumi Okita

Iridium OpenPort

Image: Hirofumi Okita

PLATO at Dome A, January 2008

Image: Zhou Xu

One year later…

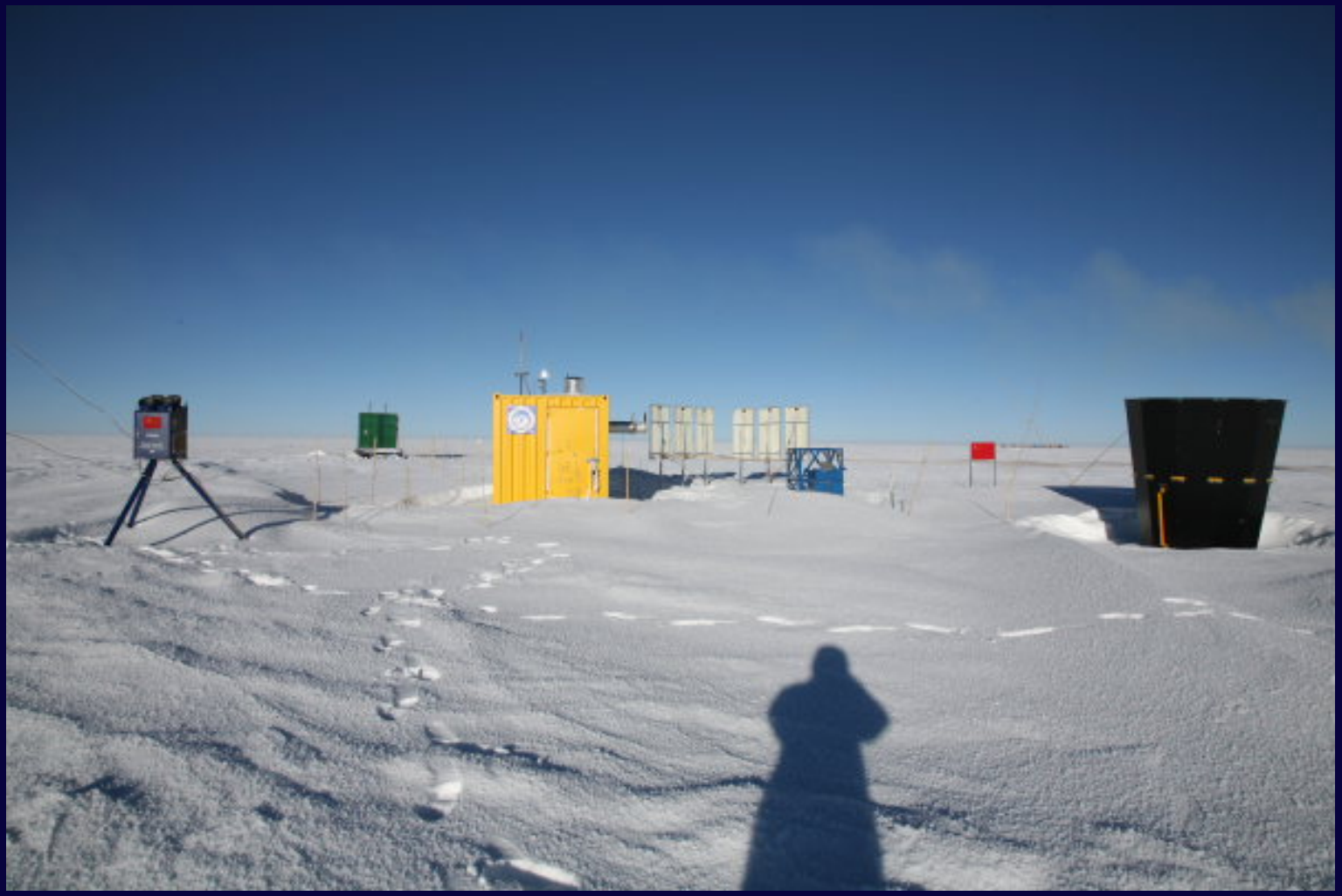
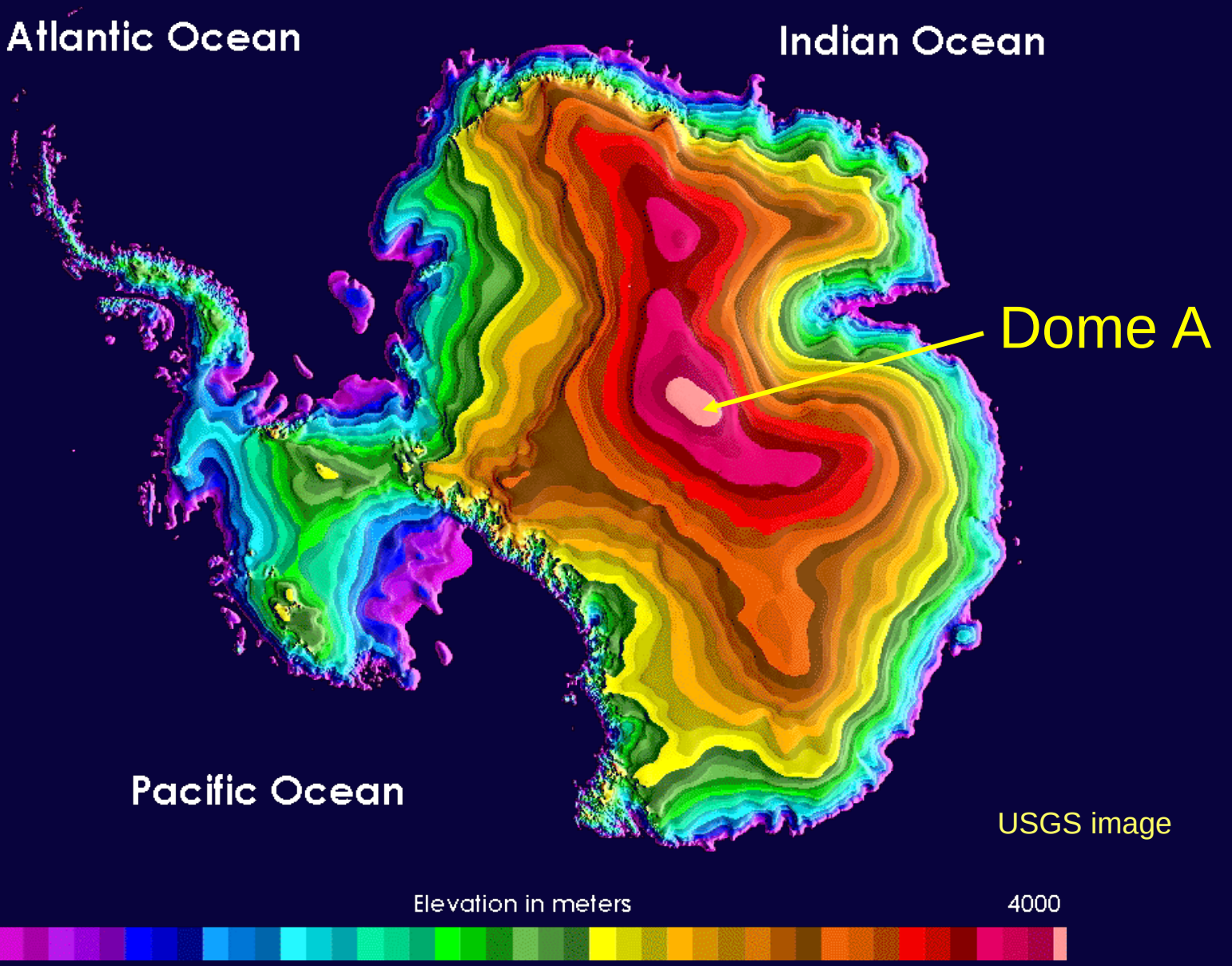


Image: Xuefei Gong

Contour map of Antarctica



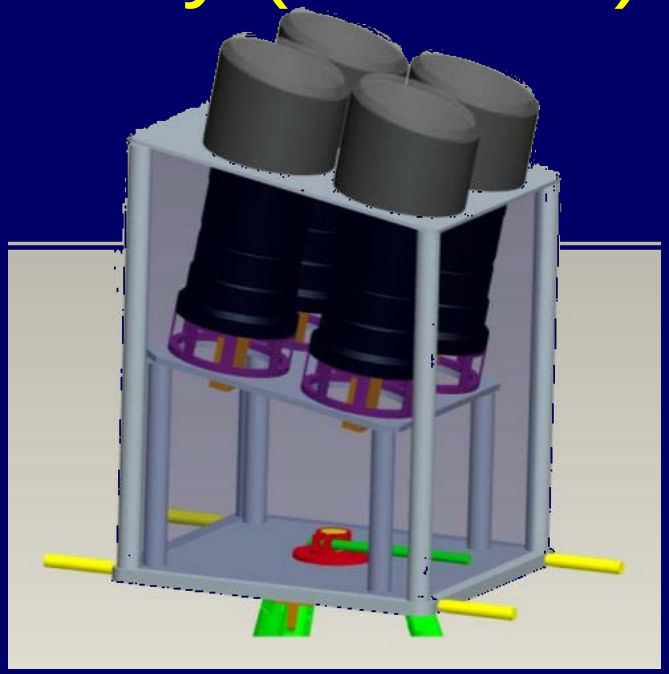
Dome A

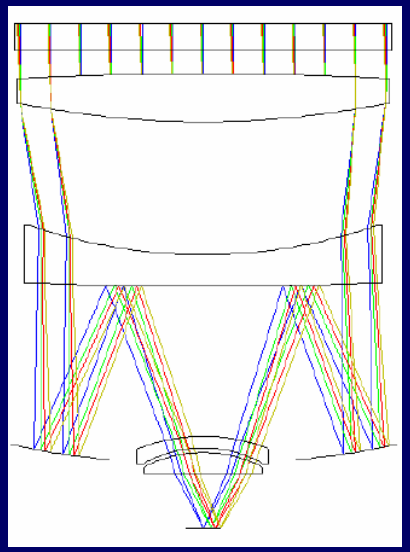
Station owner	China
Completion date	2014
Geostationary satellites visible	Almost
Advantages	Very good THz transmission Thin boundary layer
Disadvantages	Aurorae?

Dome A

Chinese Small Telescope Array (CSTAR)

- Four telescopes, each 15 cm diameter, with g, r, i and open filters
- Fixed pointing at South Celestial Pole
- No moving parts
- 1K x 1K CCD on each telescope
- 5 x 5 square degree field of view
- Continuous observations for more than 4 months, taking four images every 20 s.





Roughly 2% of images are affected by strong aurorae.

Images: NIAOT

CSTAR at Dome A

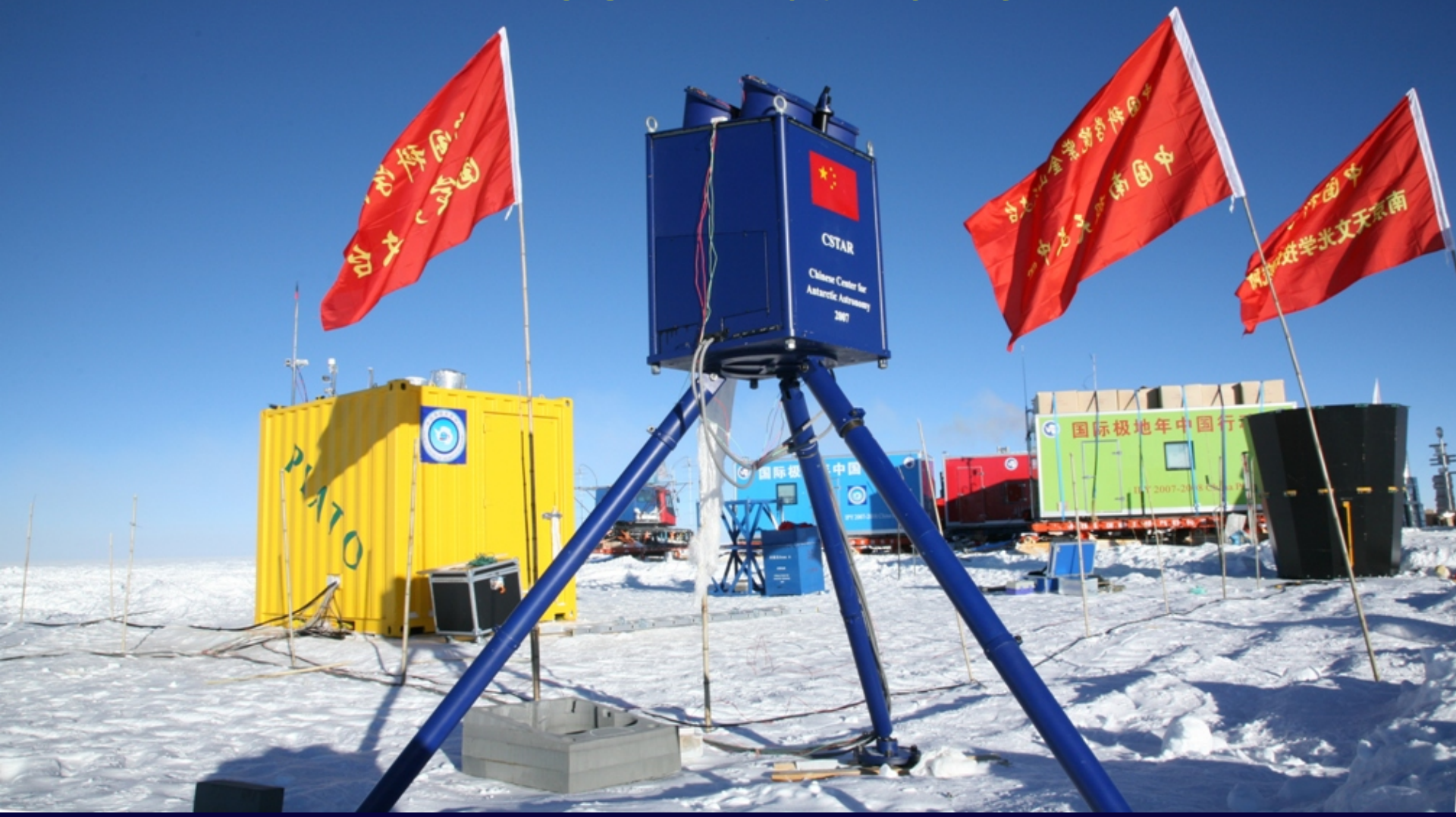
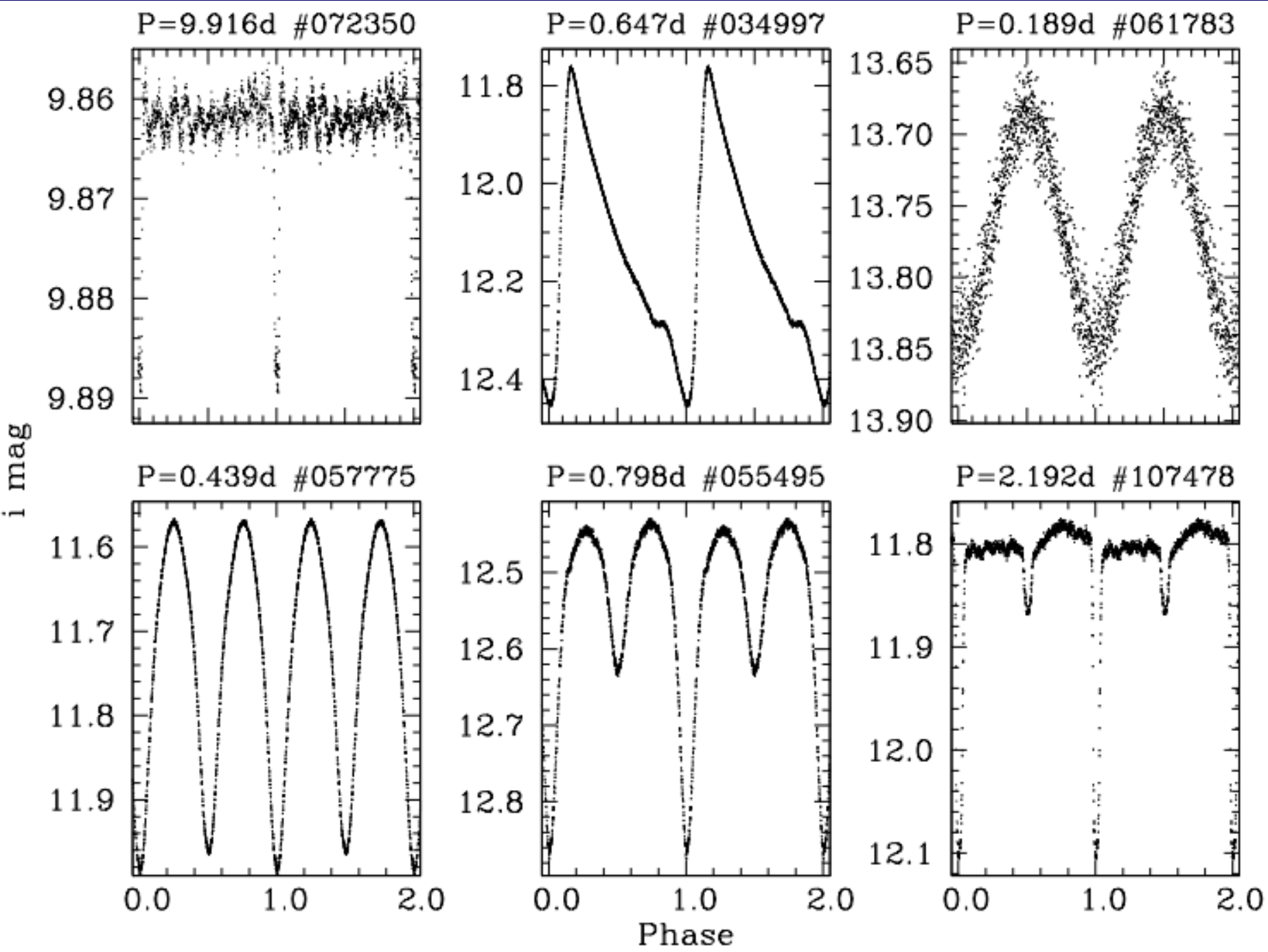


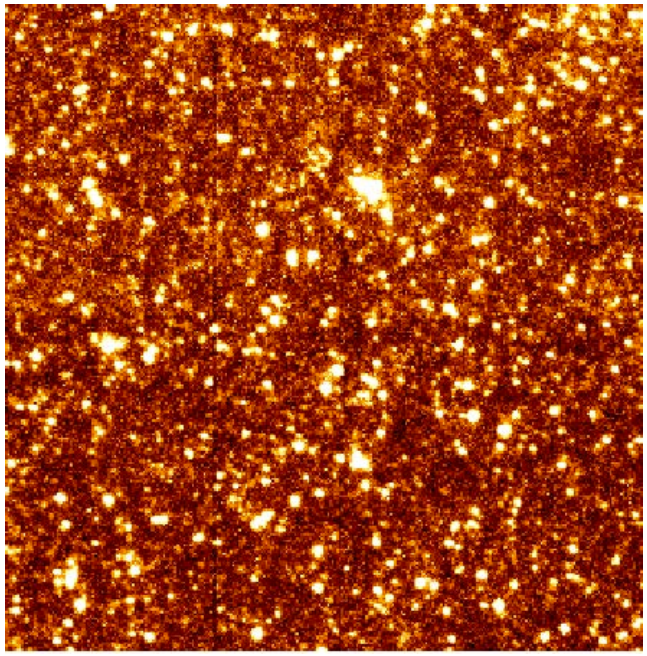
Image: Zhenxi Zhu

Image: CSTAR Science Team



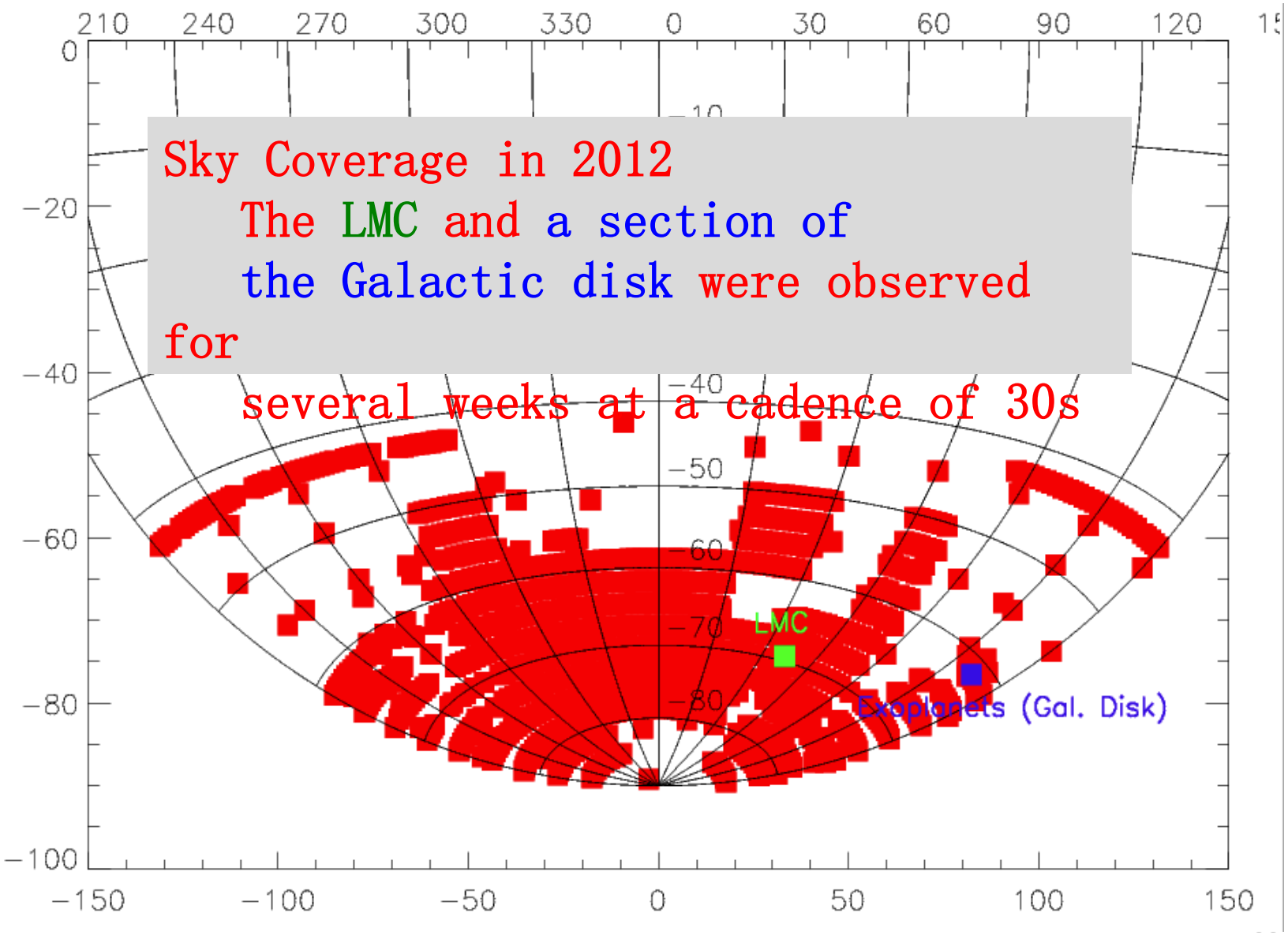
Lingzhi Wang et al., 2011

Antarctica AST 3 (Antarctic Schmidt Telescopes, 3 of)

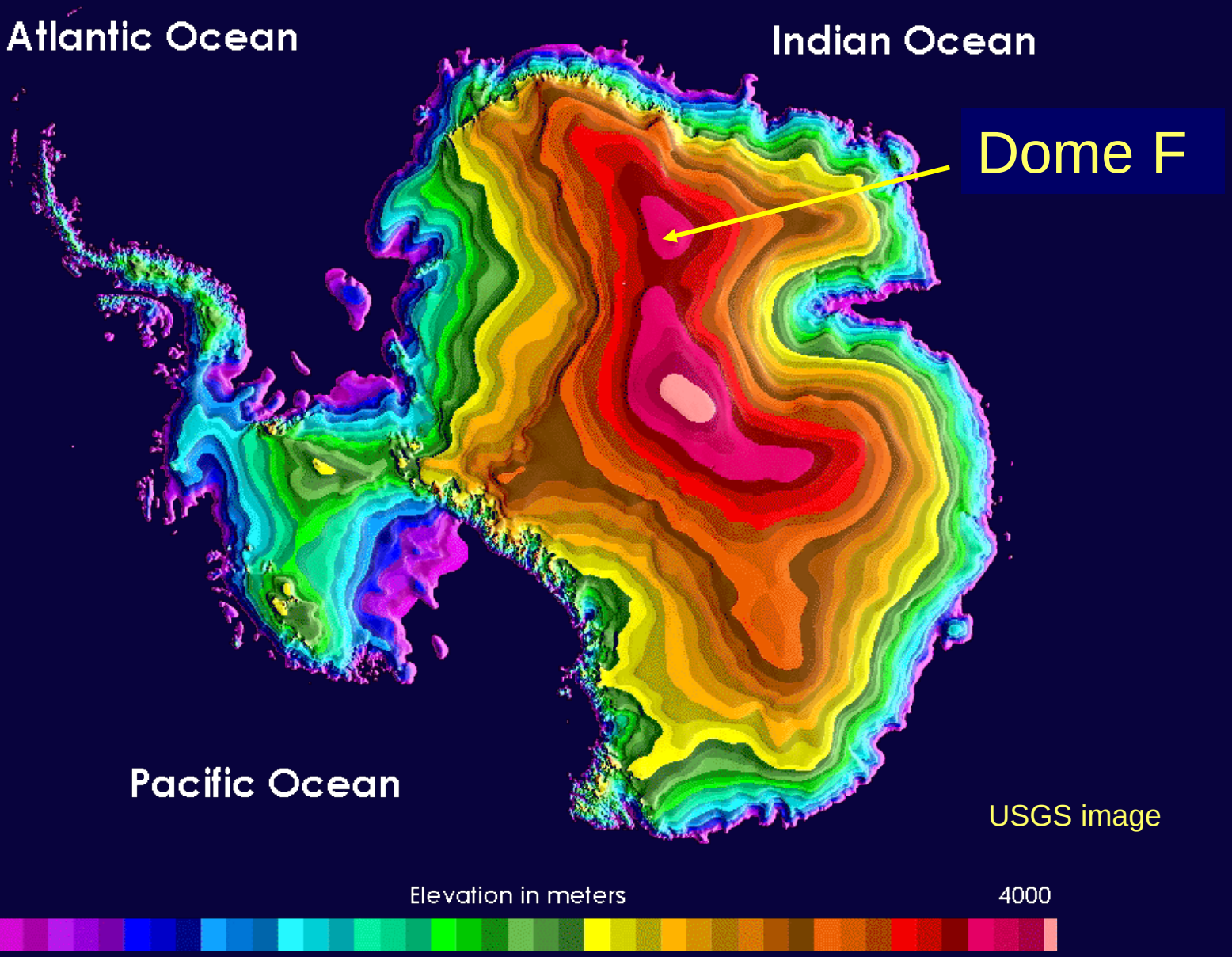


Sensitivity: 3 sigma in 1 min for an i′ =19.5

Antarctica AST 3 (Antarctic Schmidt Telescopes, 3 of)



Contour map of Antarctica



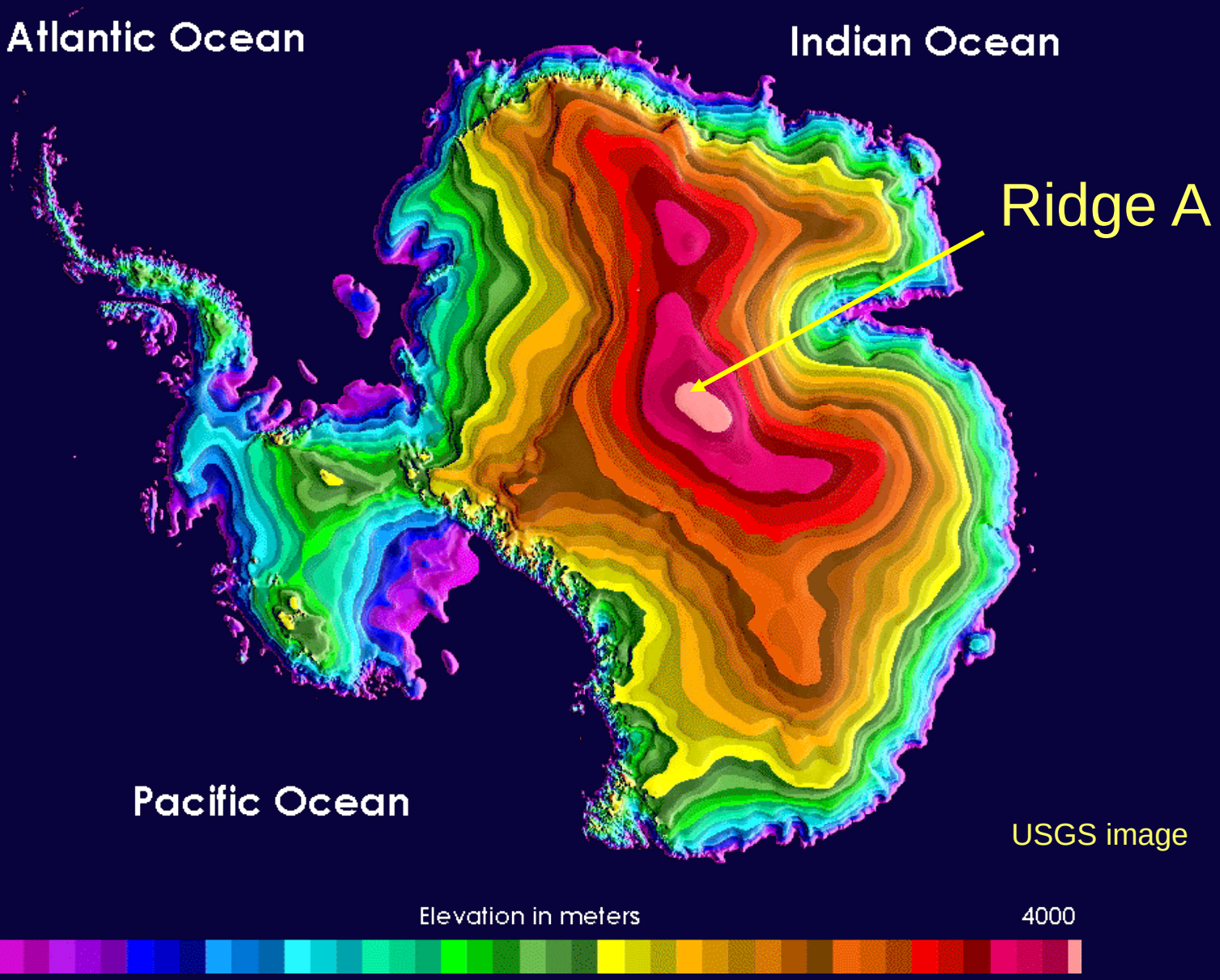
Dome F

Station owner	Japan
Completion date	?
Geostationary satellites visible	Maybe
Advantages	High
Disadvantages	Aurora

“Twincam”, the Japanese dual-channel CCD camera.

Image: Hirofumi Okita

Contour map of Antarctica



Ridge A

Station owner	Humanity
Completion date	-
Geostationary satellites visible	no
Advantages	Best overall
Disadvantages	Very little infrastructure

Identified by Saunders et al (2009) as potentially the best site on the plateau (and hence the planet) for astronomy.

Image: Luke Bycroft

PLATO-R, a field deployable observatory

Image: Luke Bycroft

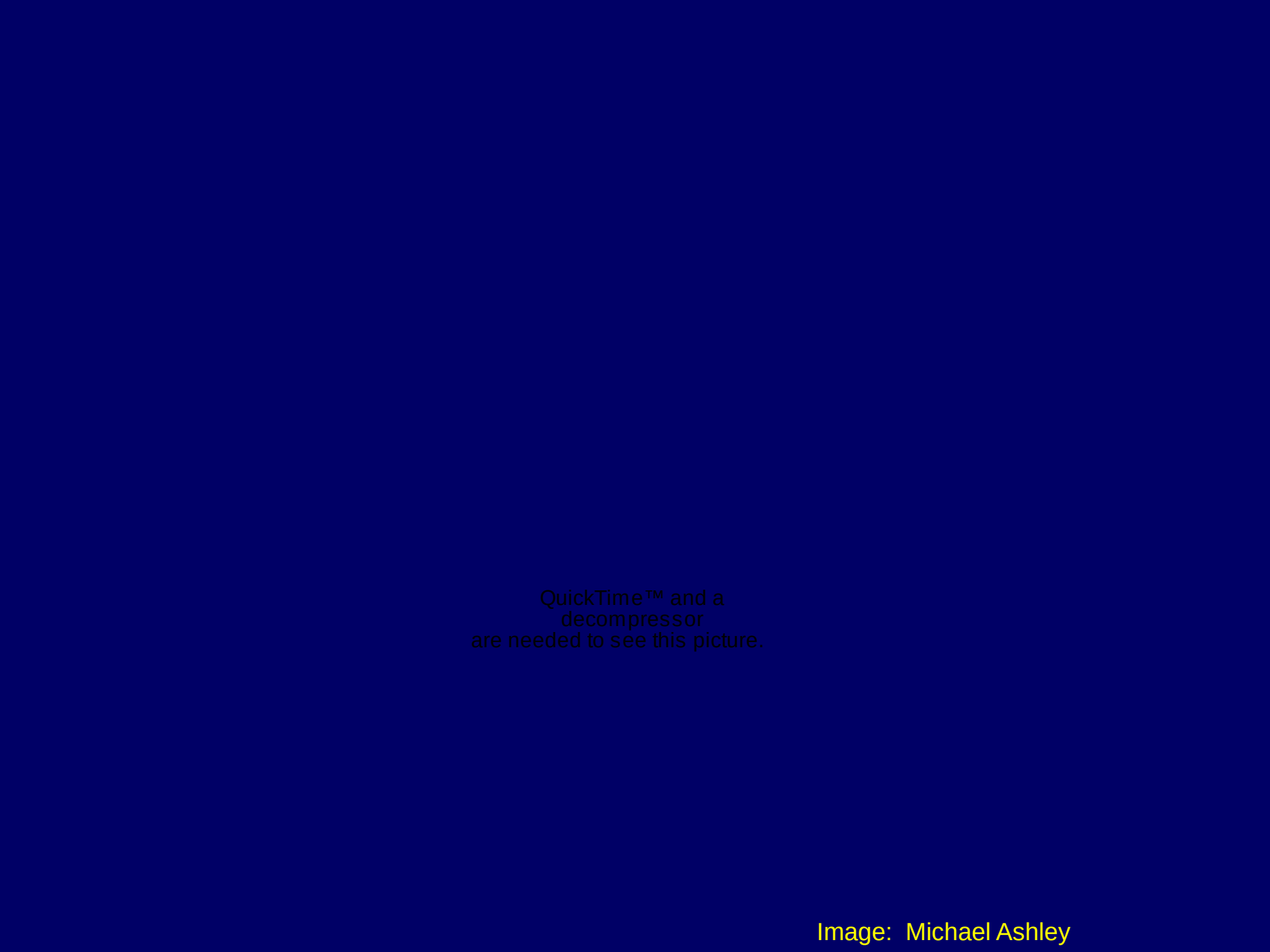
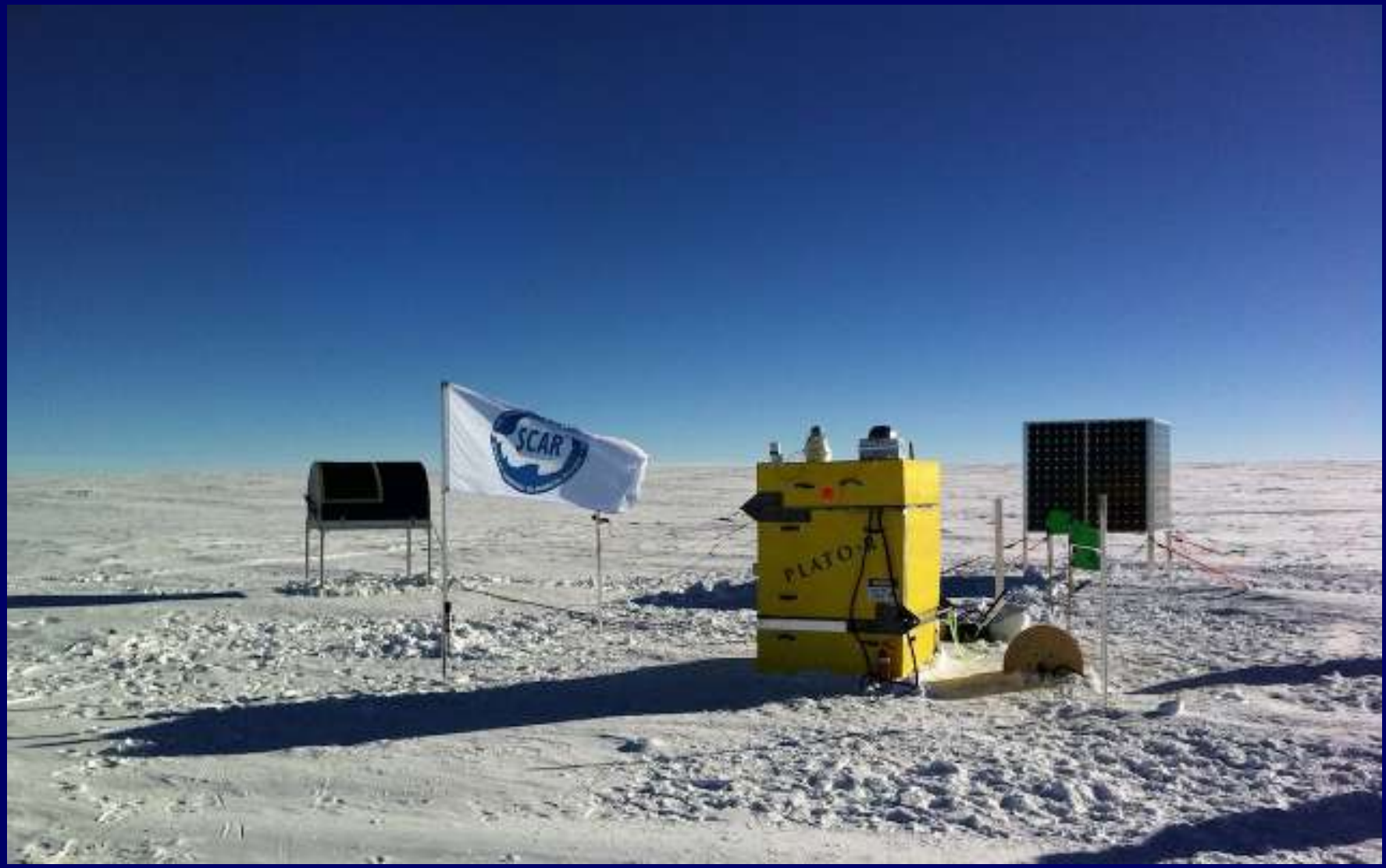


Image: Michael Ashley

QuickTime™ and a
decompressor
are needed to see this picture.

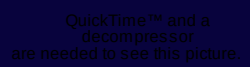
Image: Michael Ashley



Ridge A, a truly international observatory

Image: Craig Kulesa

High Elevation Antarctic Terahertz Telescope (HEAT)



- Operating band: 0.8 - 2 THz (0.8 THz in 2012)
- Closed-cycle cooled detector
- 60 cm telescope, 1´ ~ 2´ resolution
- 1 km/s spectral resolution

Image: Craig Kulesa

Routine science at 800 GHz

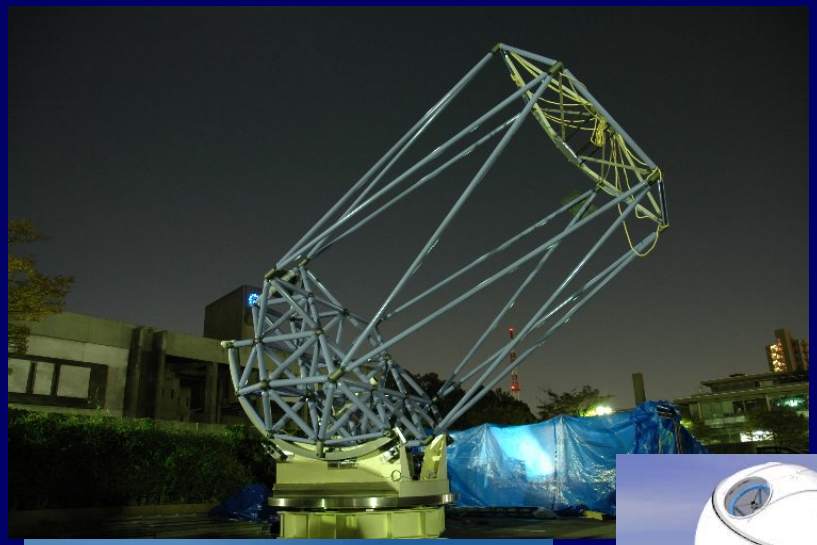
QuickTime™ and a
decompressor
are needed to see this picture.

NGC 3576

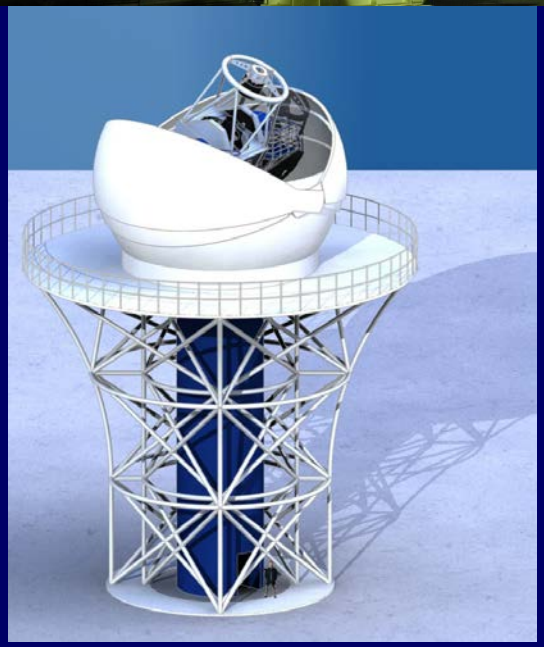
Image: Craig Kulesa

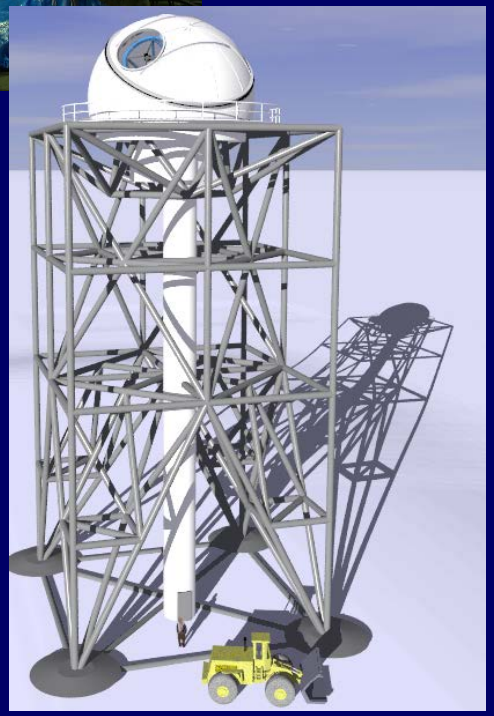
Examples of new projects

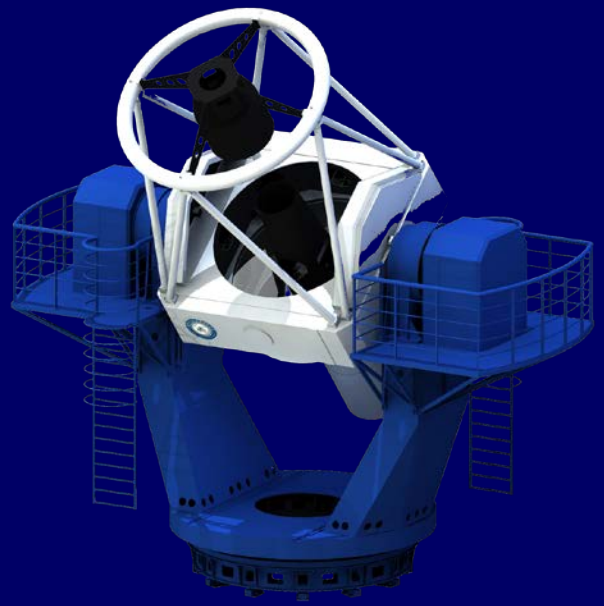
2.5 metre optical/IR telescope proposals



- PILOT (Australia/Europe)
- PLT (France/Australia)
- KDUST (China)
- Lightweight (Japan)

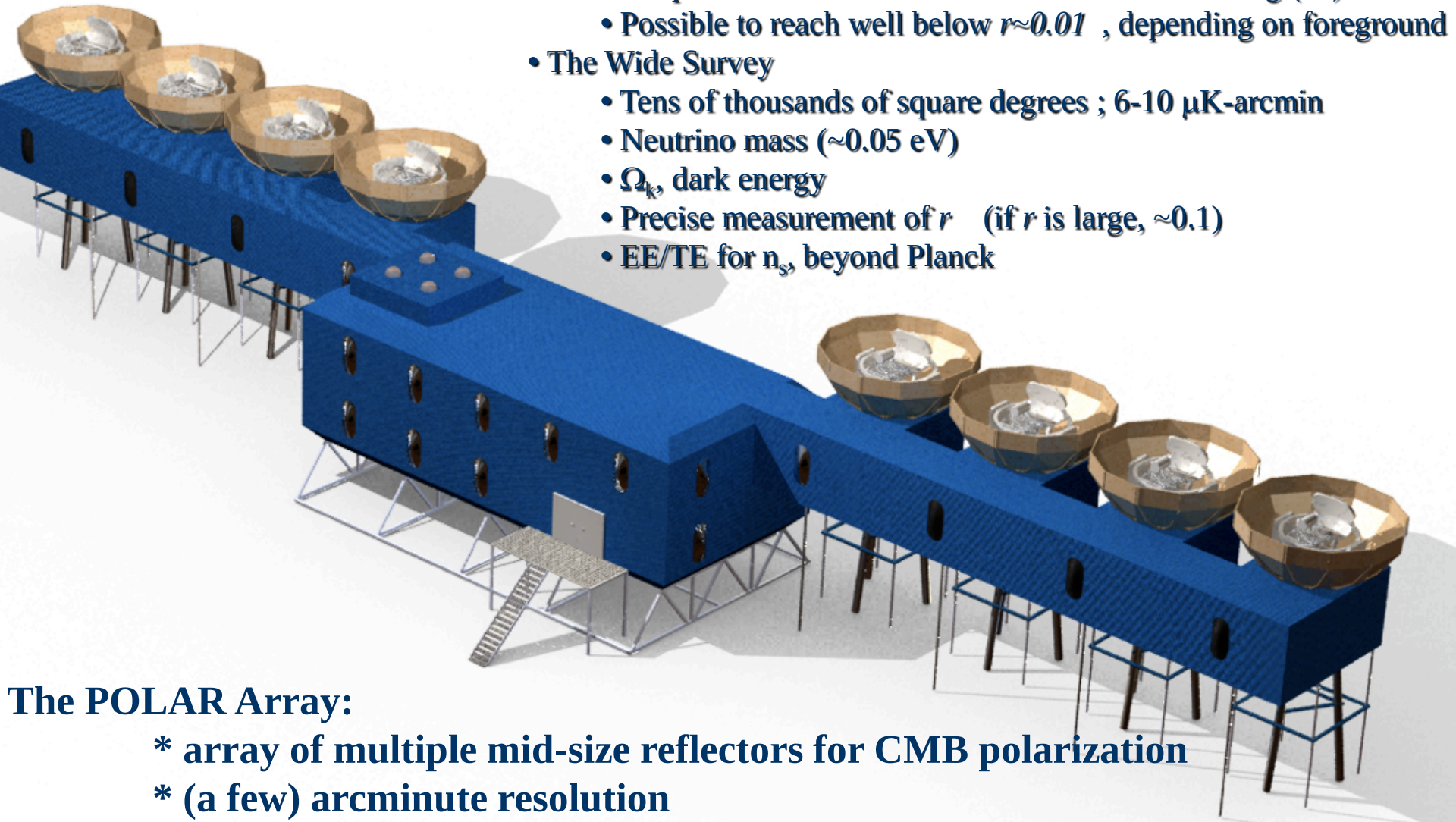






POLAR Array

- The Deep Survey
  - 400 square degrees ; 1 μK-arcmin
  - Deep search of Primordial *B*-mode with *de*-lensing (4×)
  - Possible to reach well below *r*~*0.01* , depending on foreground
- The Wide Survey
  - Tens of thousands of square degrees ; 6-10 μK-arcmin
  - Neutrino mass (~0.05 eV)
  - Ω_k, dark energy
  - Precise measurement of *r* (if *r* is large, ~0.1)
  - EE/TE for n_s, beyond Planck



The POLAR Array:

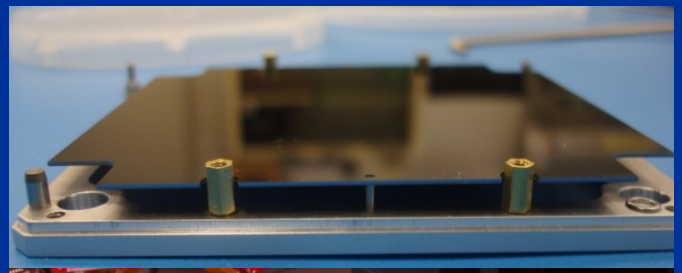
*** array of multiple mid-size reflectors for CMB polarization**

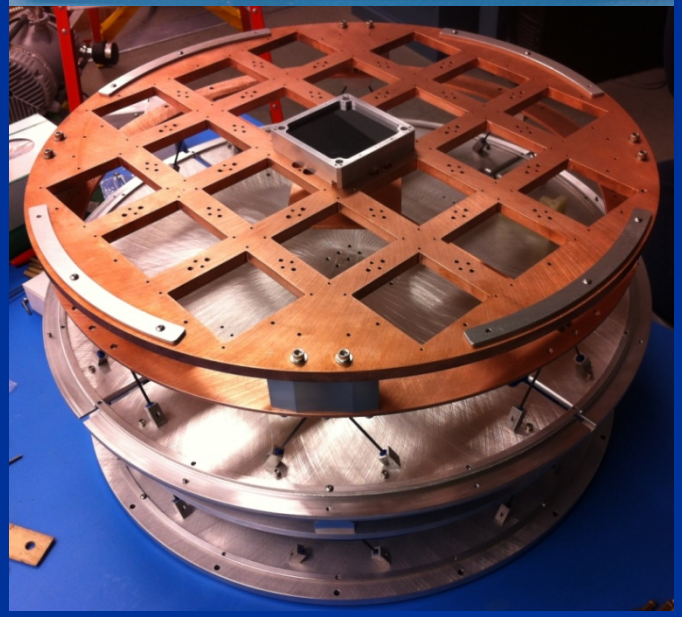
*** (a few) arcminute resolution**

*** multi-frequency (distribution TBD)**

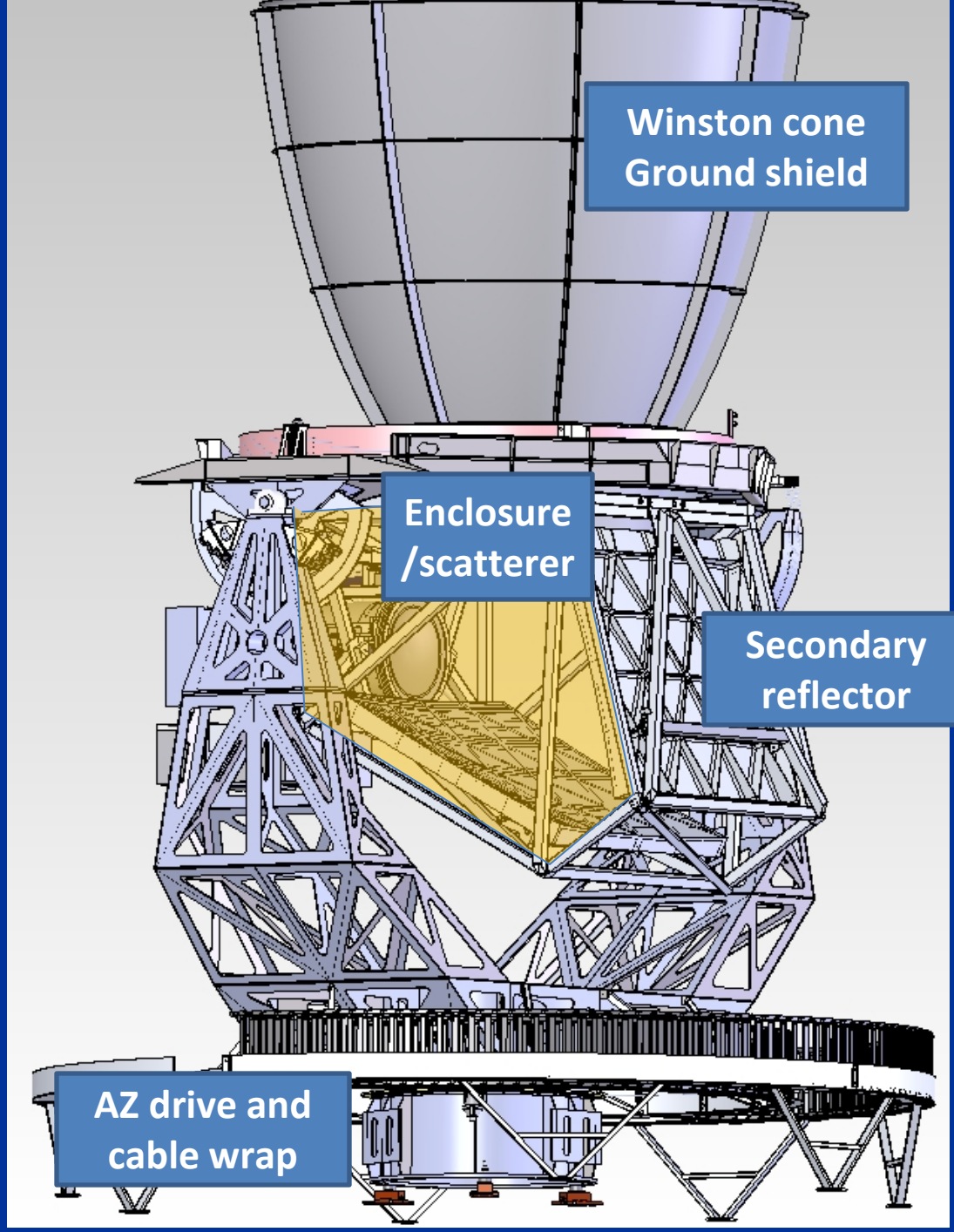
*** 10% the survey speed of CMBPOL**

POLAR-1 (pathfinder)





- Modular focal units, tiled together to form large focal plane
- Large $A\Omega$, simple optics
- Spillover scatterer + Winston shield
- Boresight angle rotation
- Aiming for 2013 deployment



Greenland & Ellesmere Island


Alert
SUMMIT
10°C (50°F) isotherm, July
Arctic Ocean
CANADA
RUSSIA
UNITED STATES
Greenland (DENMARK)
North Atlantic Ocean
Scale 1:39,000,000
Azimuthal Equal-Area Projection
http://www.lib.utexas.edu/maps/polar.html

Coming soon:

SCAR OSCXXXII SCAR
and Open Science Conference
Antarctic Science and Policy Advice in a Changing World
13 - 25 July 2012
Portland, OR, USA

IAU Symposium 288
Astrophysics from Antarctica
IAU XXVIII General Assembly
20 - 31 August 2012
Beijing, China

Coming even sooner:

"Design of telescopes for Extreme Environments"

Posters:
Conference 8444; Tuesday 1800 t0 2000 hrs
8444-203 to 8444-210

Oral talks:
Conference 8444; Wednesday 1540 to 1750 hrs
8444-58 to 8444-63