Sky coverage of interferometry and the Antarctic

John Storey

With contributions from

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THE UNIVERSITY OF NEW SOUTH WALES

SYDNEY · 2052 · AUSTRALIA

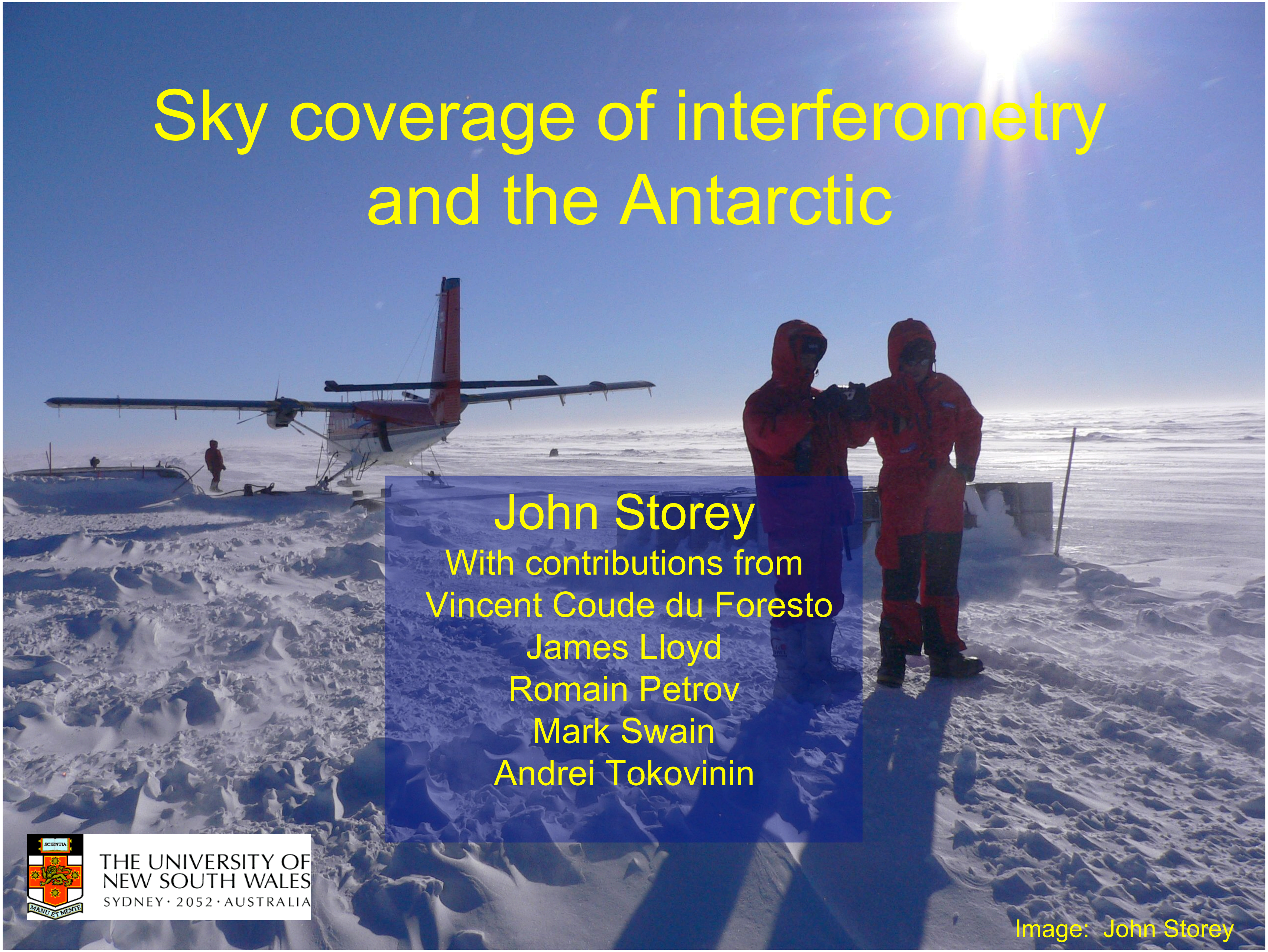

Image: John Storey

Outline

- Where is Antarctica?
- Site conditions and sky coverage
- Is it practical?
- More on site testing
- Towers
- Some current ideas

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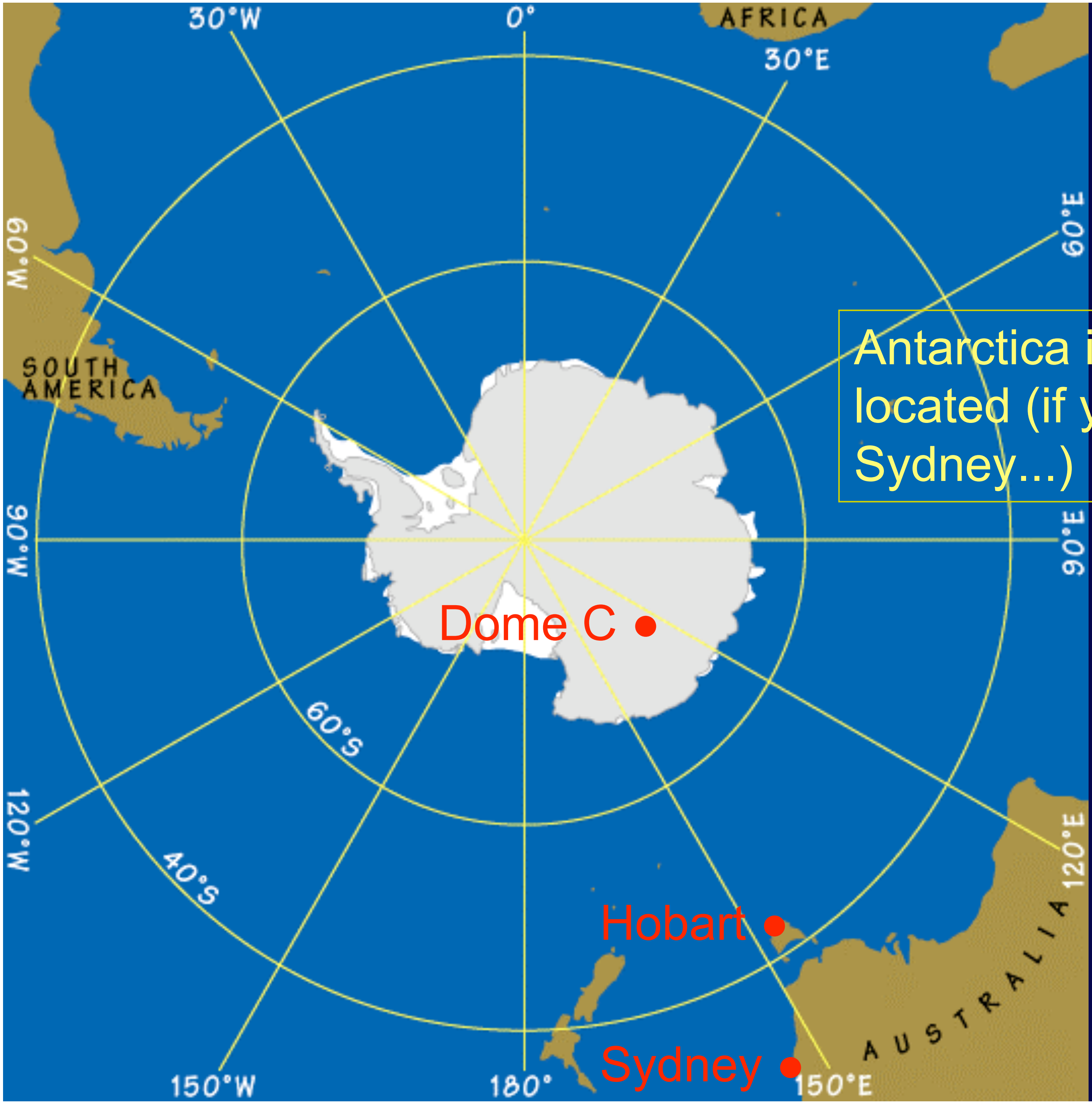


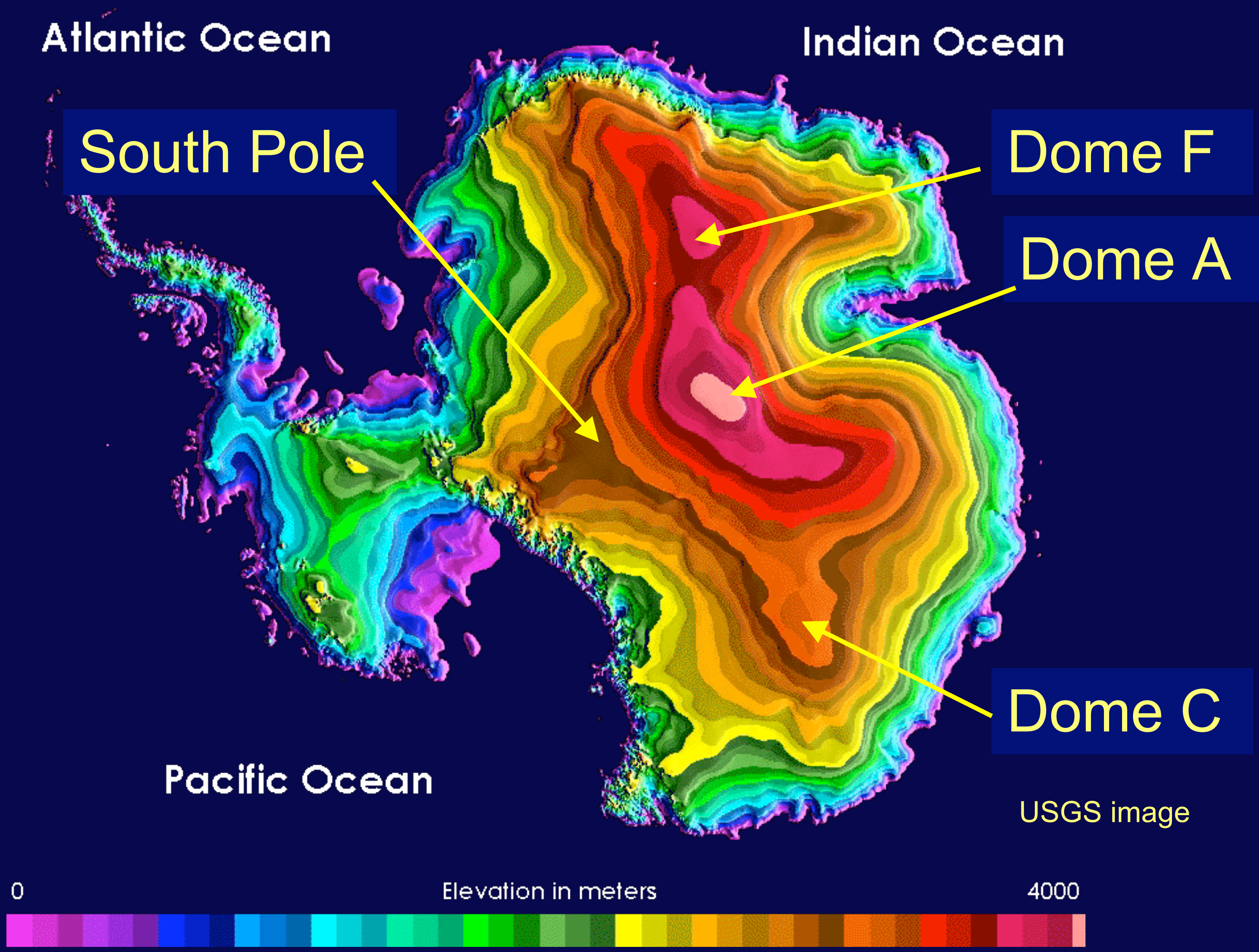
Antarctica is conveniently located (if you live in Sydney...)

Image: Australian Antarctic Division

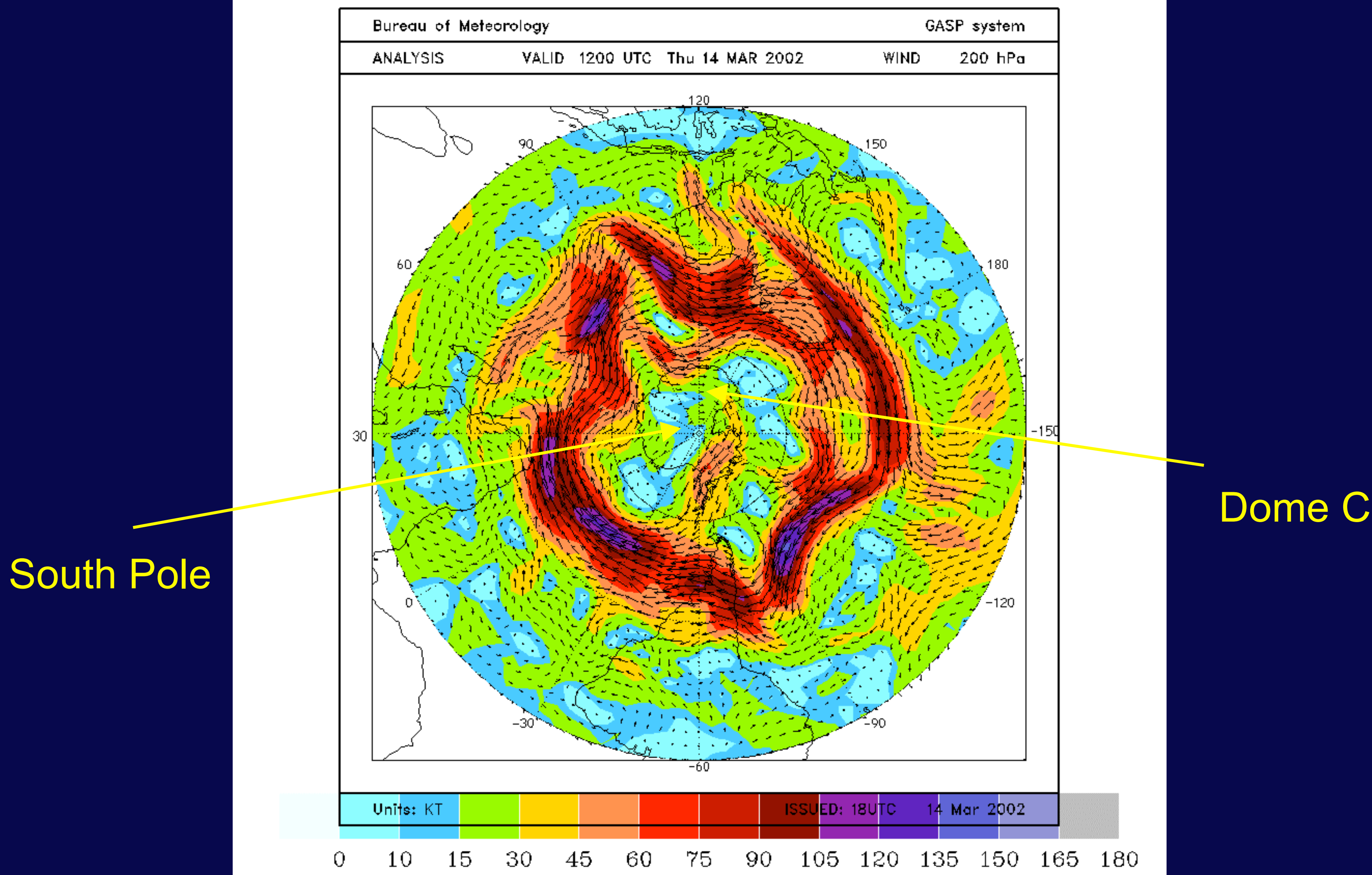
Dome C is 15^o from the South Pole.

Image: Guillaume Dargaud

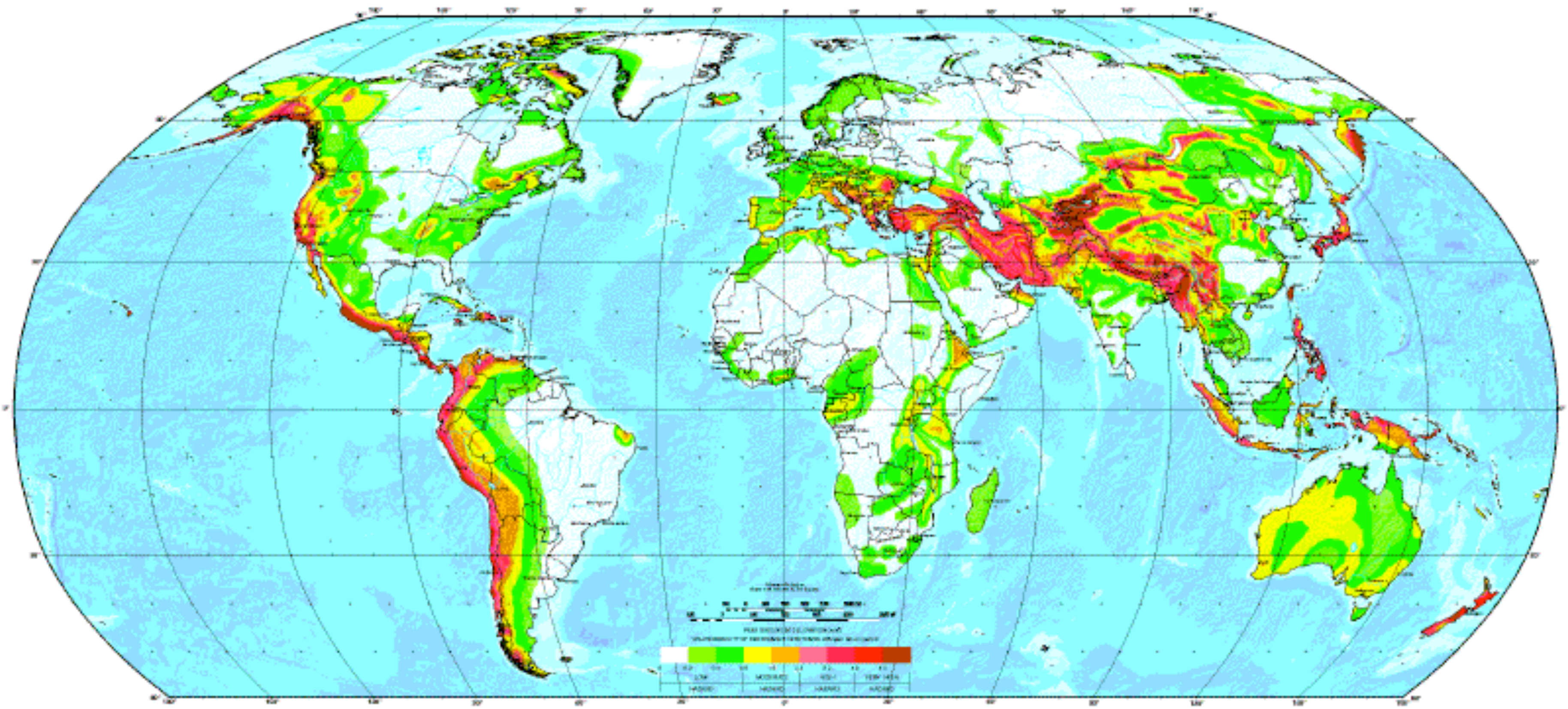
Contour map of Antarctica



The Jet Stream

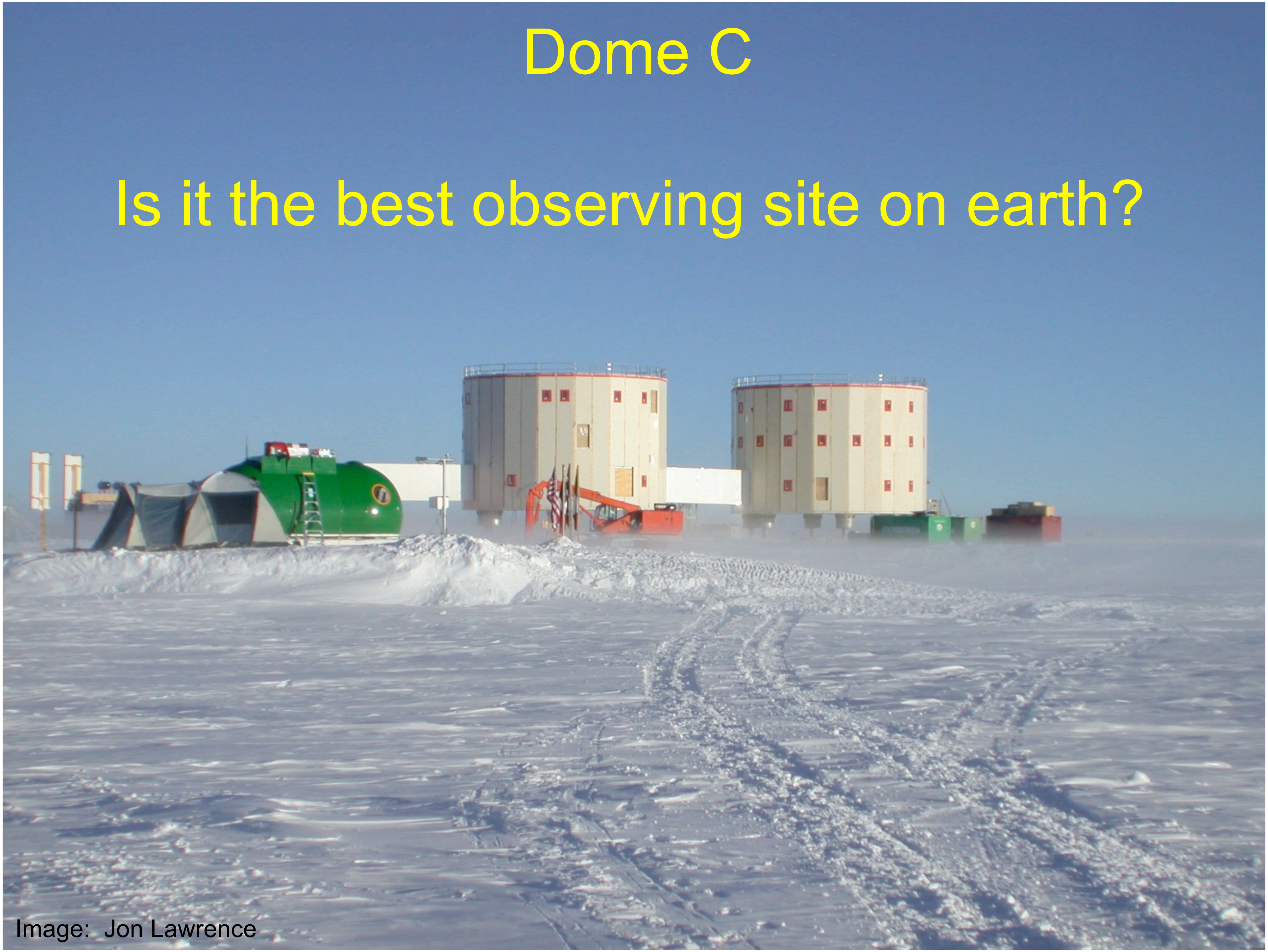


GLOBAL SEISMIC HAZARD MAP



Peak Ground Acceleration up to 5m/s²: 10% probability of exceedance in 50 years

Source: http://www.seismo.ethz.ch/GSHAP/


Dome C
Is it the best observing site on earth?
Image: Jon Lawrence

Maybe, but the Chinese are also planning a permanent station at Dome A...

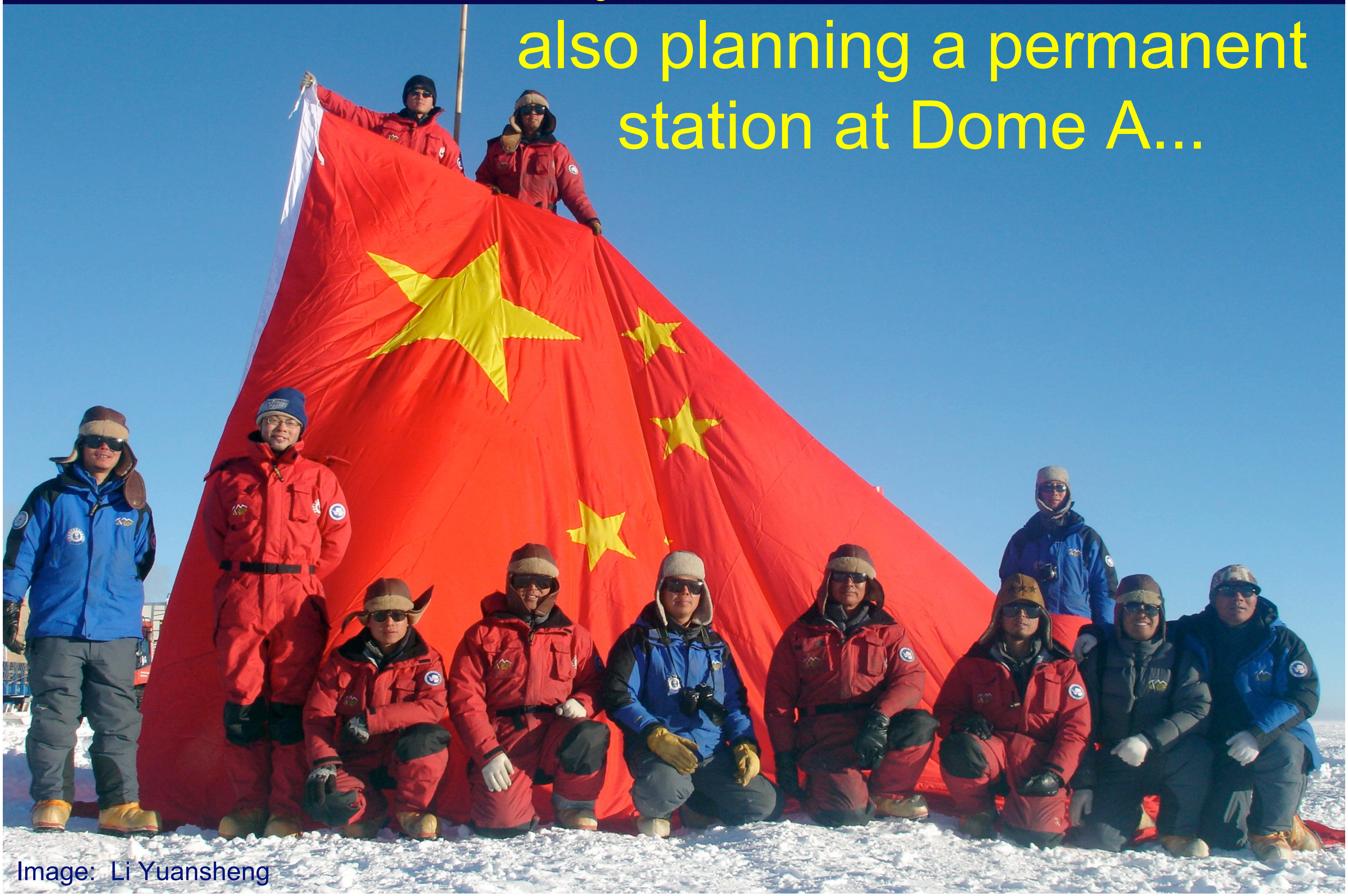


Image: Li Yuansheng

Image: Patrik Kaufmann

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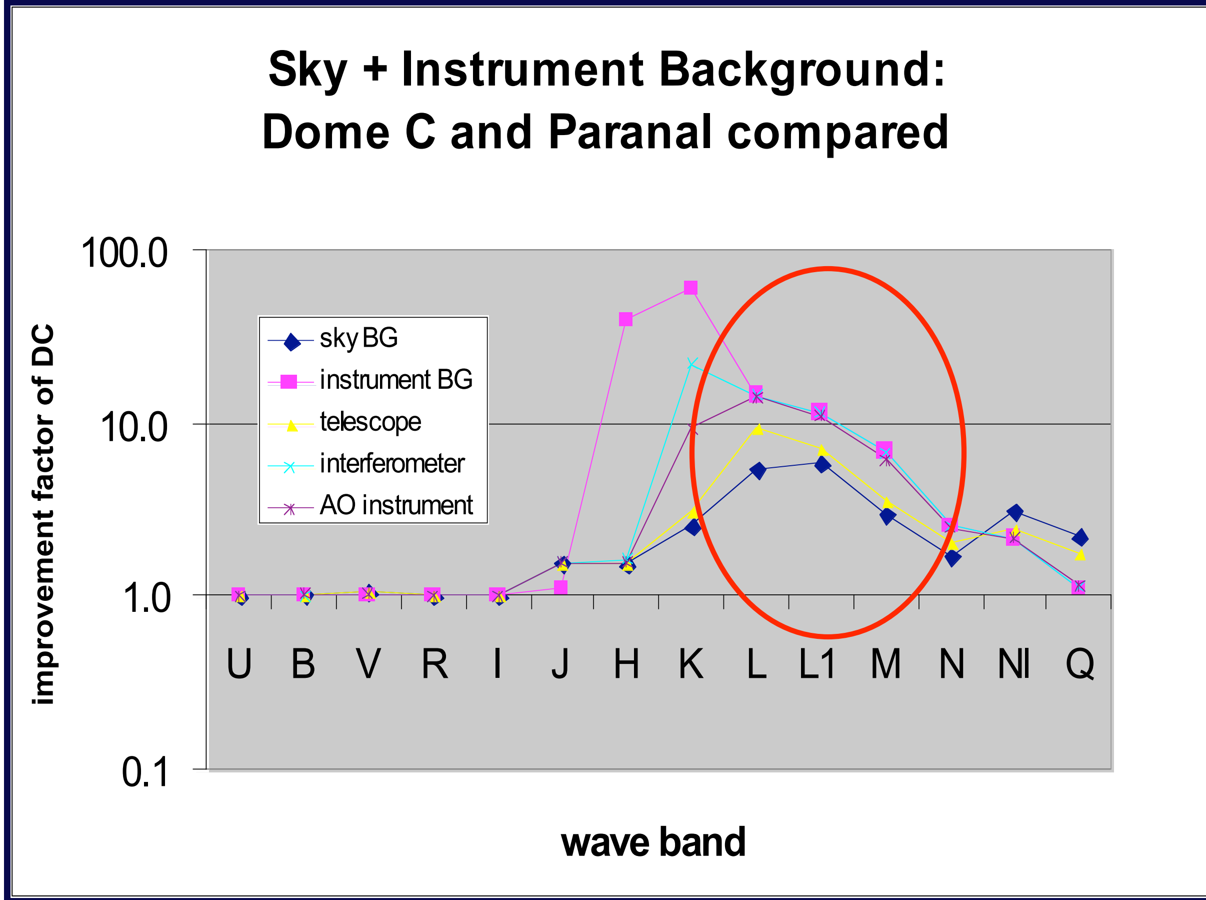
Dome C versus conventional sites

- Seeing (above 30 m) 2 – 3x better
- Isoplanatic angle 2 – 3x larger
- Coherence time 2.5x longer
- Scintillation 3 – 4x less
- IR background 20 – 100x less
- Aerosols up to 50x lower

Image: Paolo Calisse

Background reduction 2-5 μm

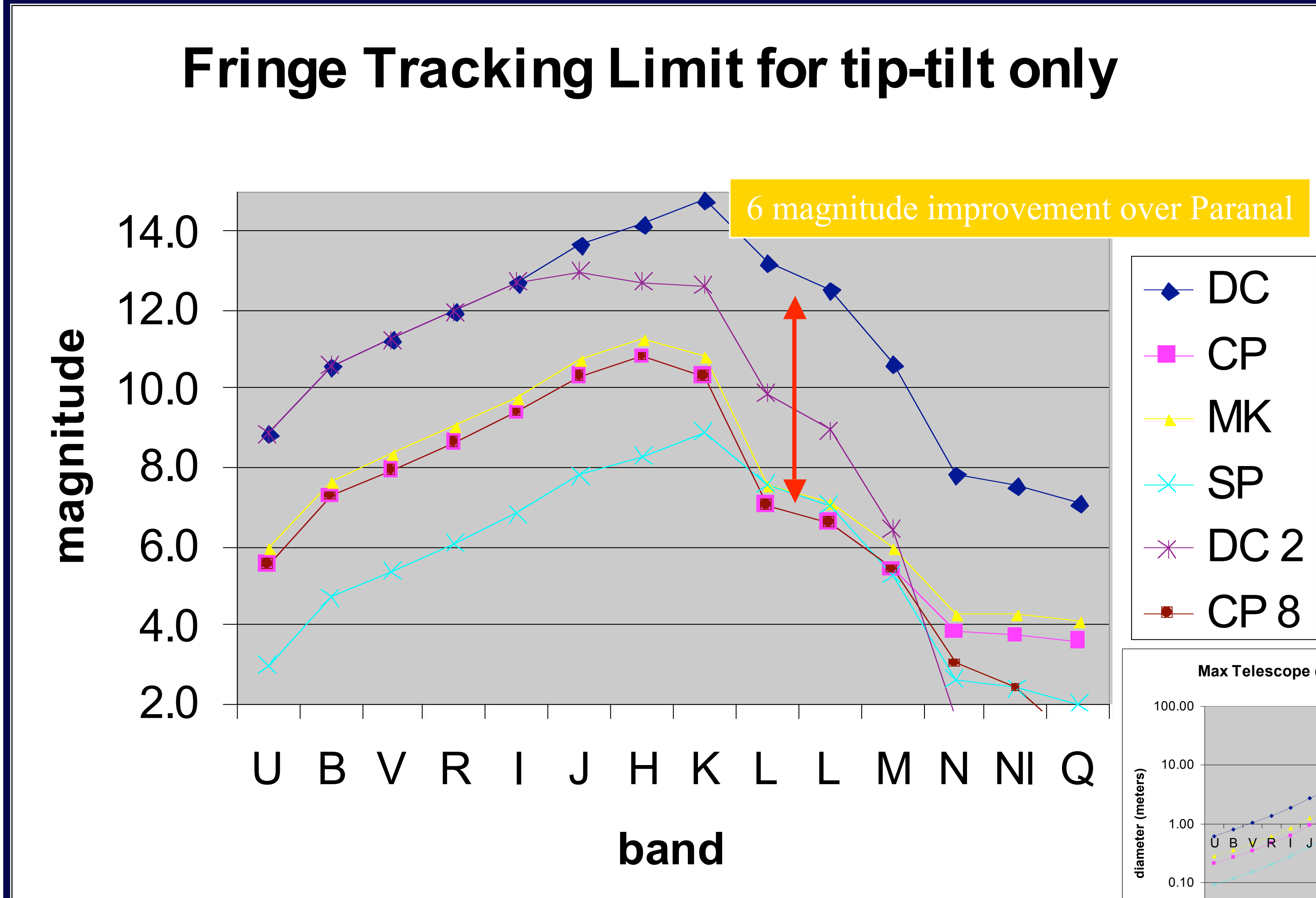


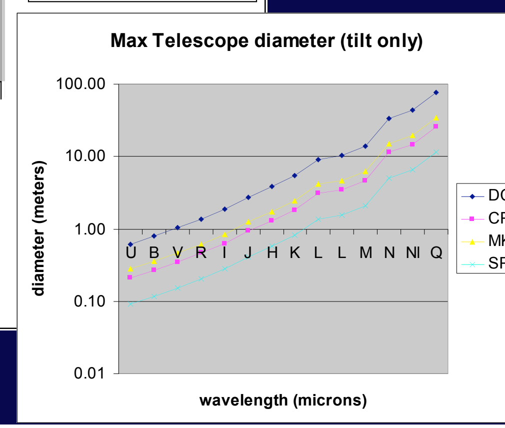
Sky and instrument background contributions differ.

Net background controlled by emissivity and transmission.

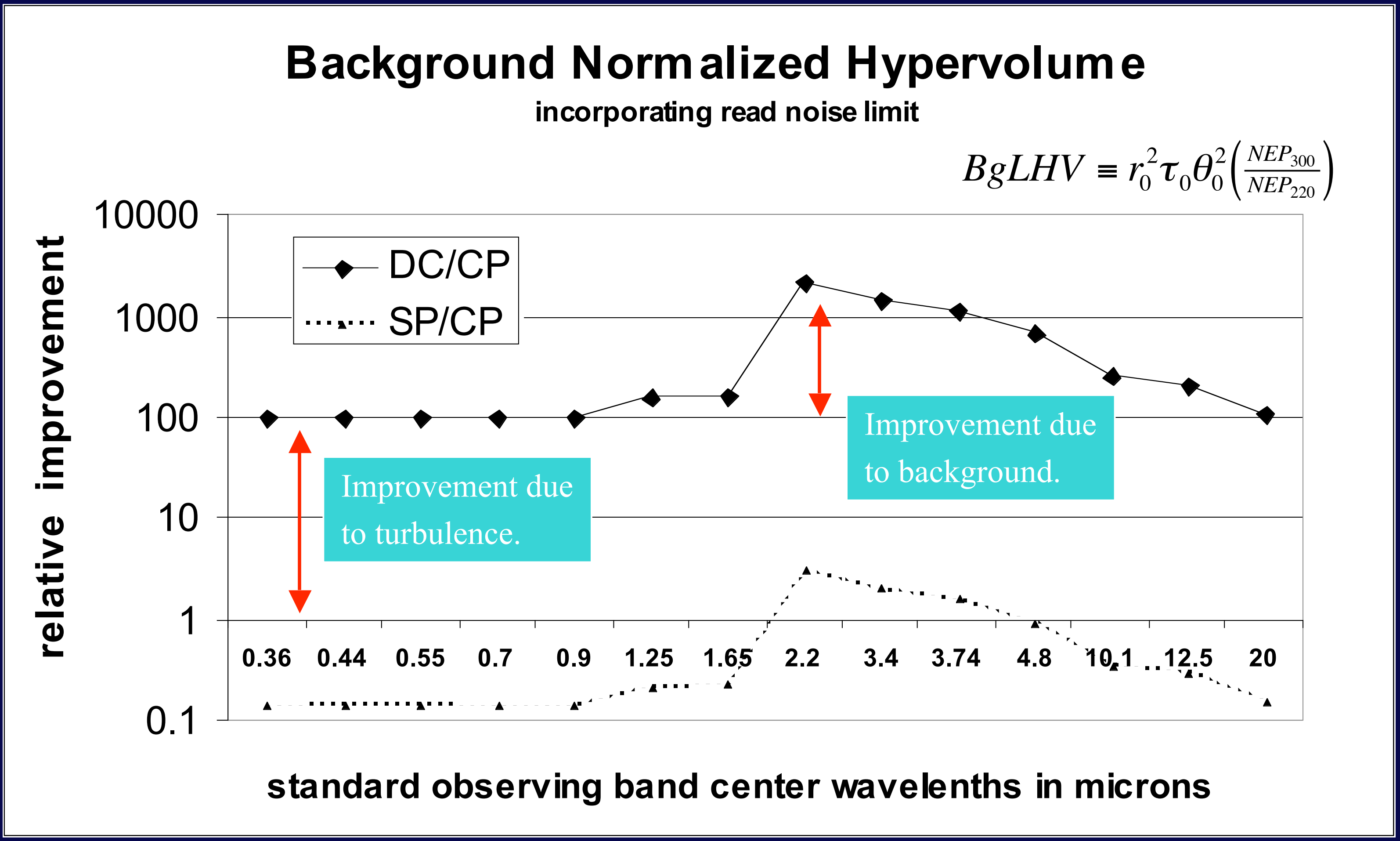
Instruments couple to background components differently.

Interferometry at Dome C

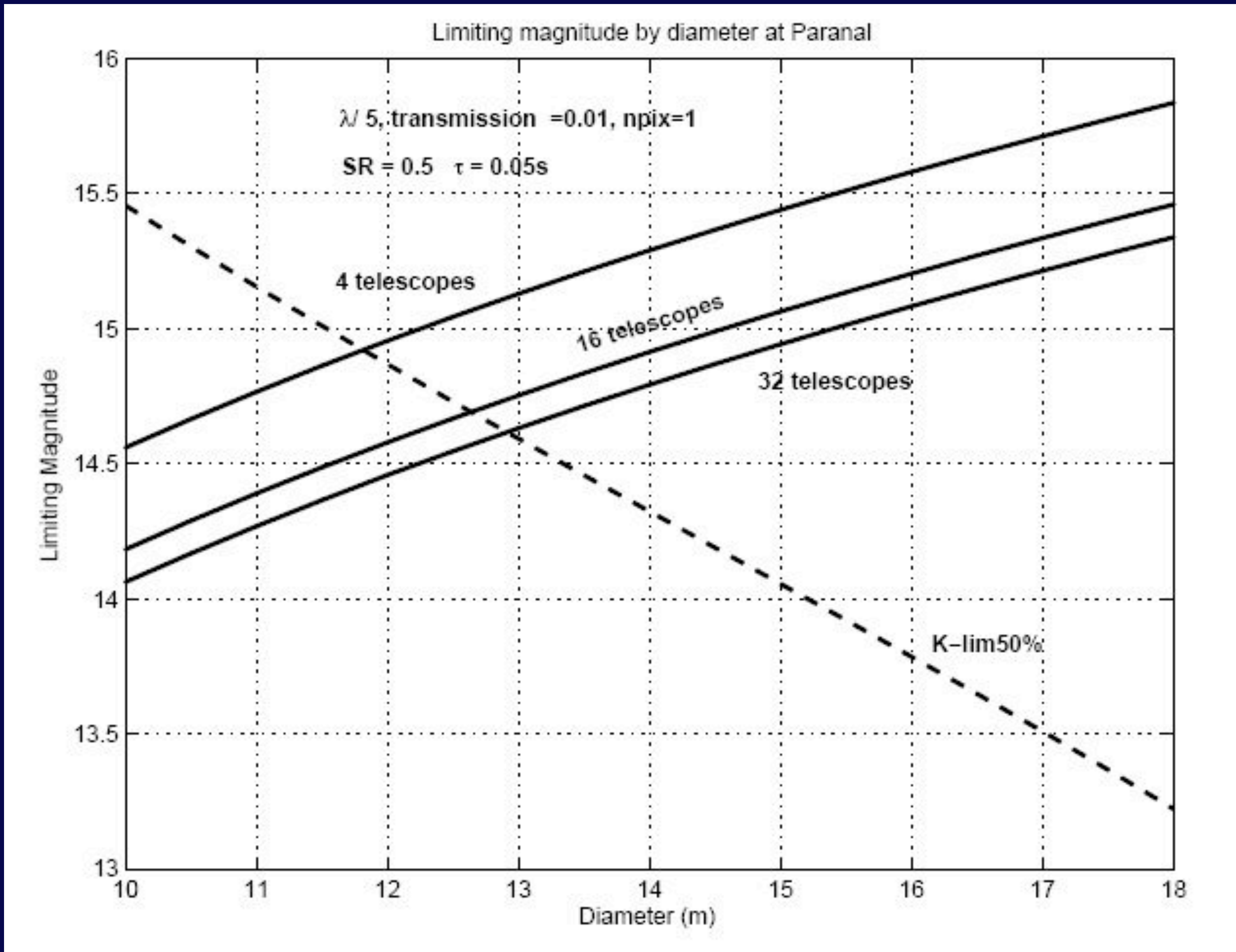




Phase Referenced Interferometer & AO potential at Dome C



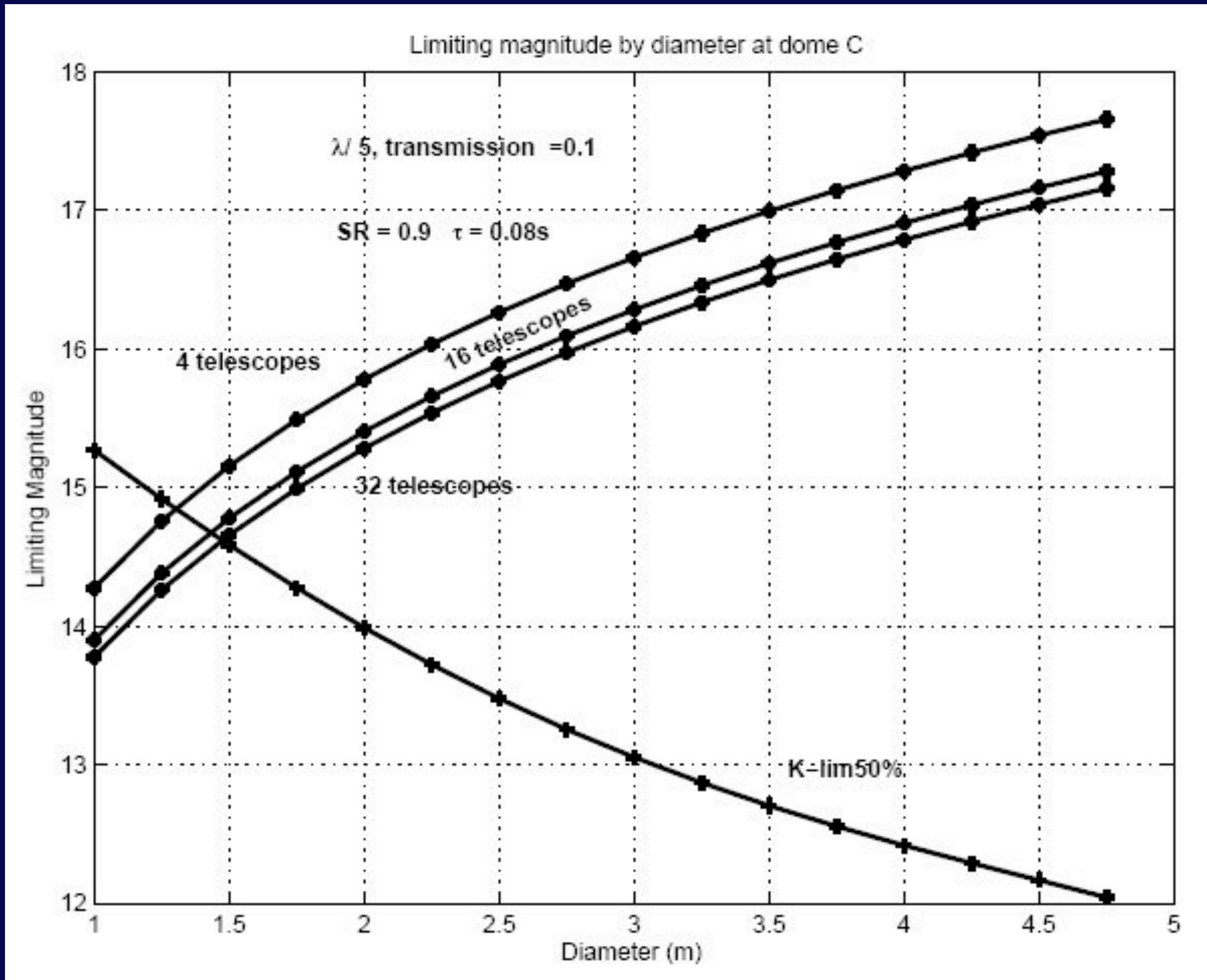
Swain, Toulouse conf. proceedings.



Paranal:

Elhalkouj et al, 2006

Fried Parameter=9cm, L_0 = 25m, θ_0= 1.9 arcsec, K-band

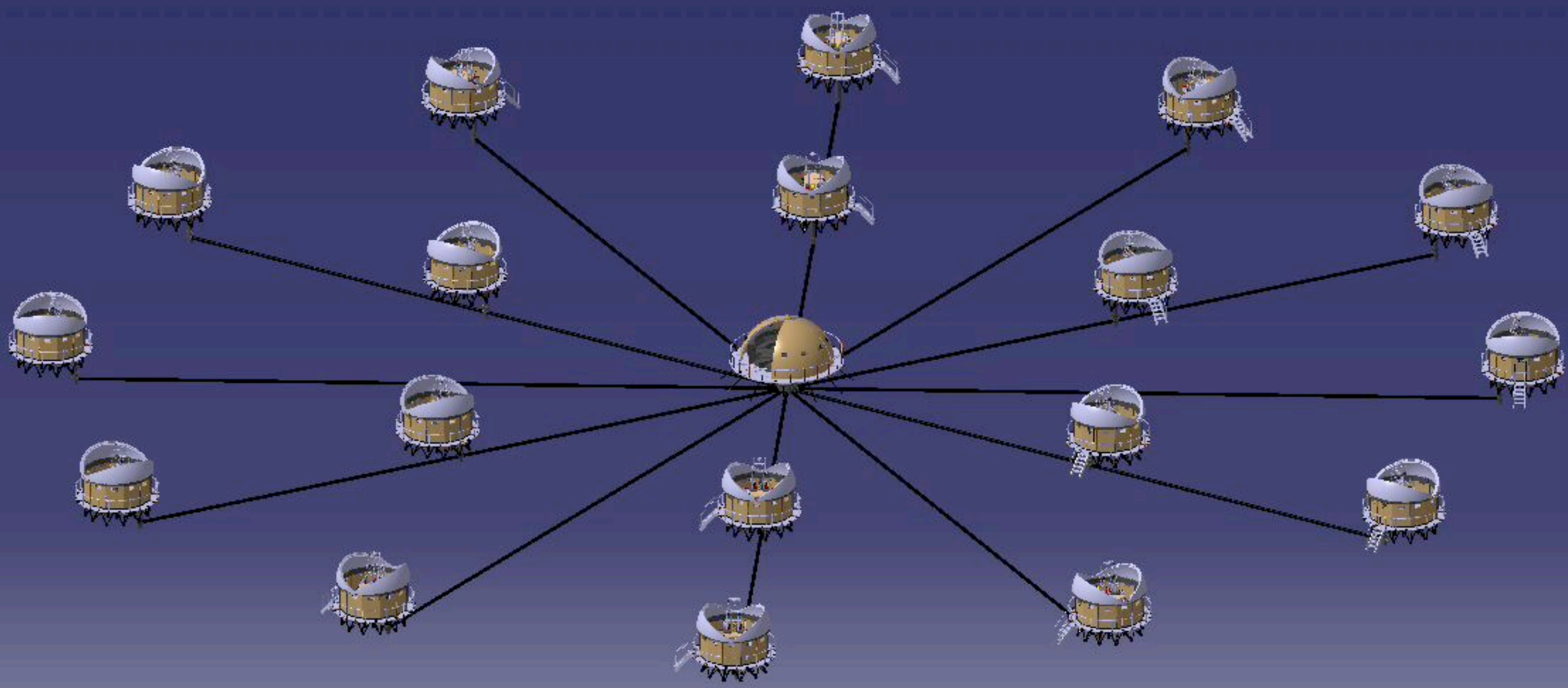


Dome C:

Elhalkouj et al, 2006

Fried Parameter =5cm, L_0 = 10m, θ_0= 5.3 arcsec, K band

KEOPS



F. Vakhili, University of Nice


Image: Patrik Kaufmann

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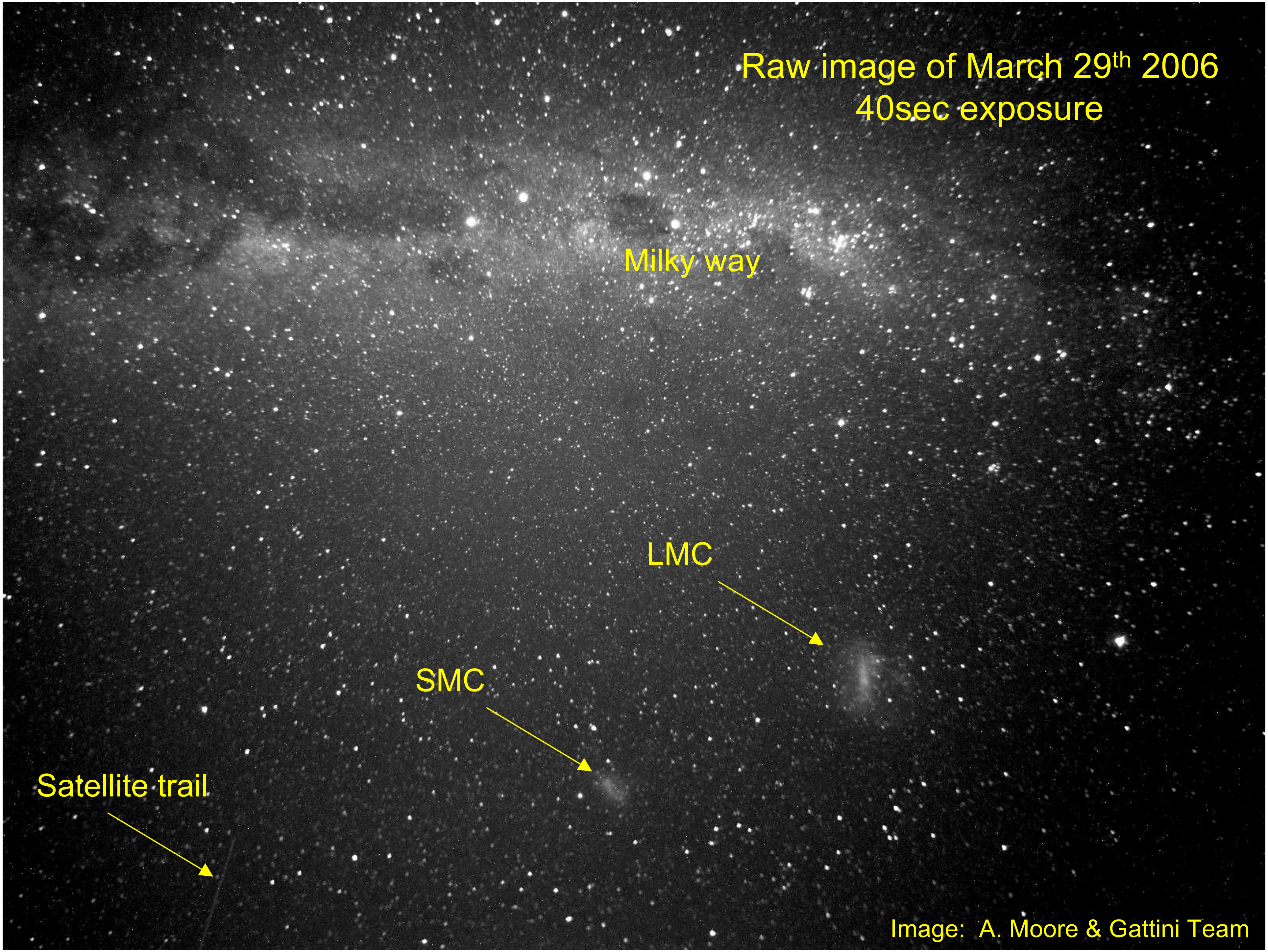
The real disadvantages:

- See less of sky
- Less “dark time” (?)
- Ecliptic always low
- Physical isolation in winter
- Difficult to work outside in winter
- “Diamond dust” close to ground
- Wind gusts and icing at 30m (?)

Image: Karim Agabi


Raw image of March 29th 2006
40sec exposure
Milky way
LMC
SMC
Satellite trail
Image: A. Moore & Gattini Team

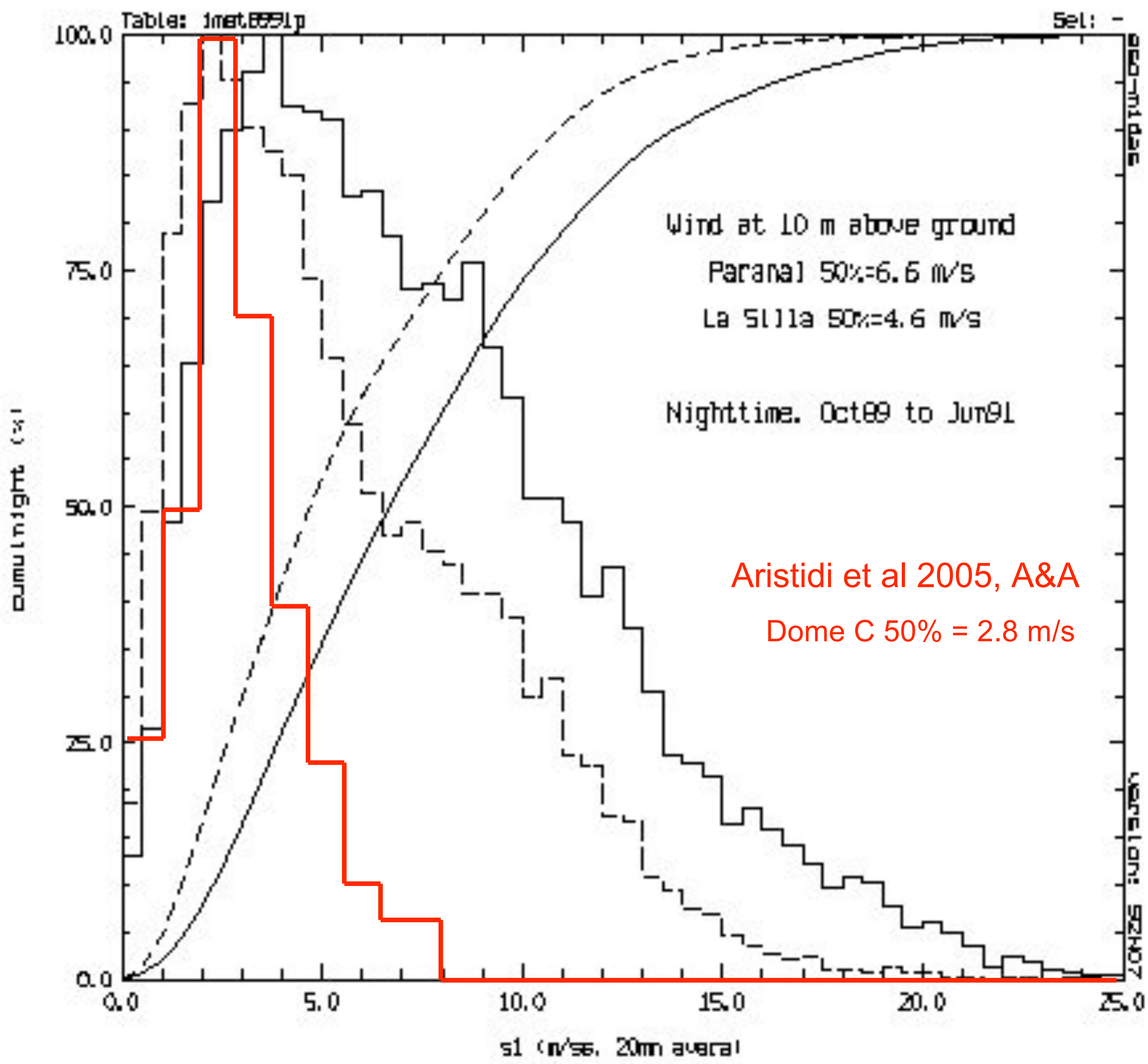
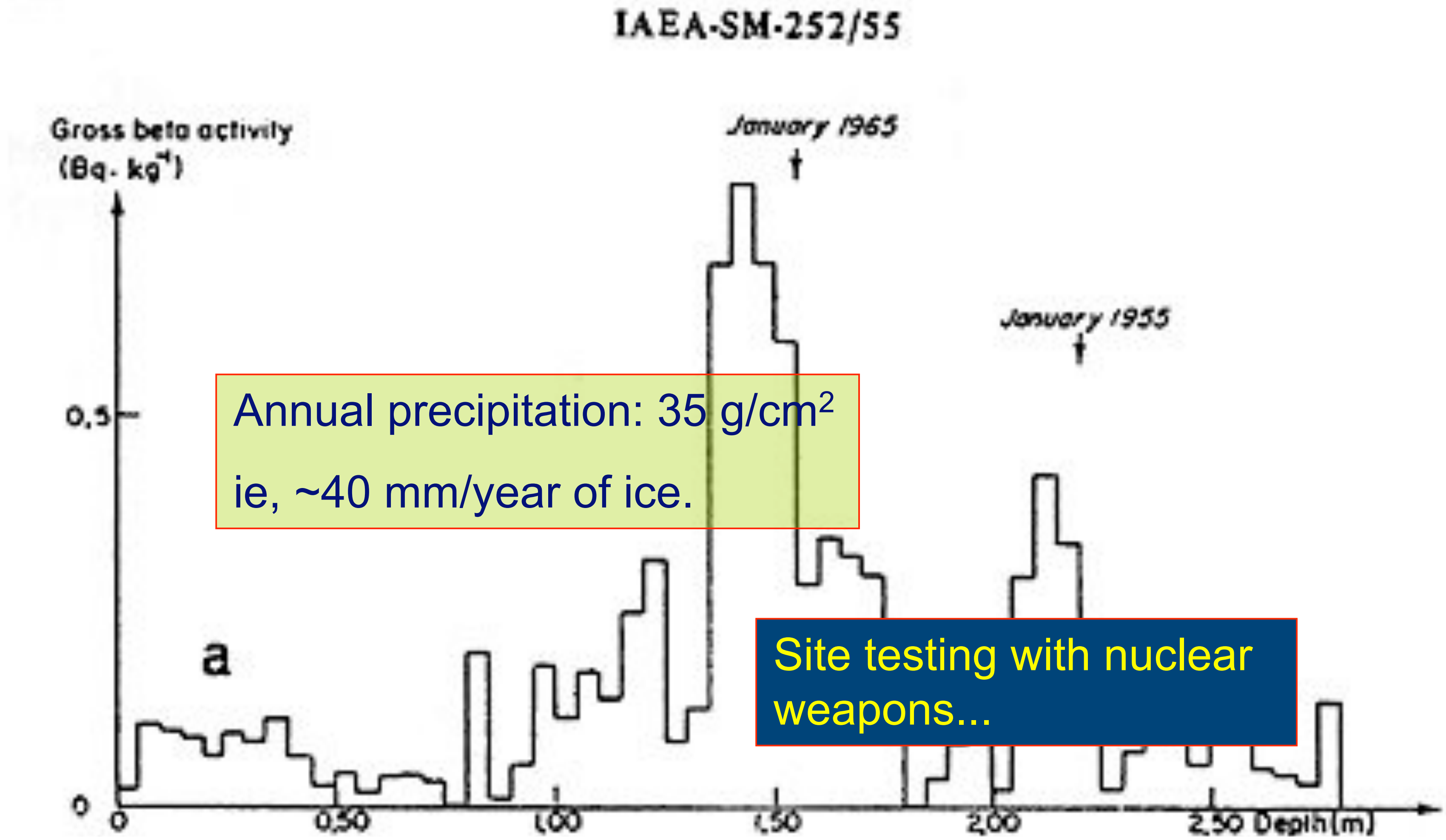


Table: imet8991p
Sel: -
100.0
75.0
50.0
25.0
0.0
5.0
10.0
15.0
20.0
25.0
cumulnight (%)
s1 (m/ss, 20mn aveal)
Wind at 10 m above ground
Paranal 50%=6.6 m/s
La Silla 50%=4.6 m/s
Nighttime, Oct89 to Jun91
Aristidi et al 2005, A&A
Dome C 50% = 2.8 m/s

Myth #5: The violent snow storms will bury the telescope...

Image courtesy Keck Observatory, Mauna Kea.


Dome C
November 2003
Image: John Storey



Ice core taken in 1978

Launch costs to LEO

- Rocket $15,000/kg
- Shuttle $60,000/kg

- Dome C $5/kg

NSF C130 Hercules can carry 20 tonnes.

PNRA logistical support of Dome C by air.

Image: John Storey

French traverse from Dumont d'Urville to Dome C.

- Three traverses/year (currently)
- Each traverse delivers ~150 tonnes
- Twelve-metre sleds – essentially no size or weight restrictions

Image: John Storey

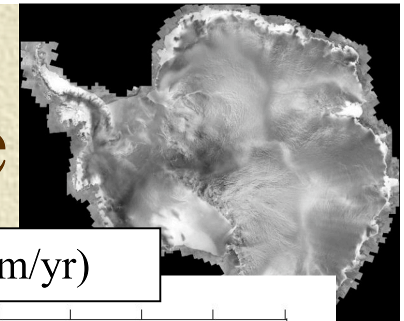
Complete 2-metre telescope (minus mirror)

Image: Electro-Optic Systems


And one more...
Another 2 m telescope
2 m telescope
CATERPILLAR
CATERPILLAR
1
65
CHALLENGER
Image: John Storey

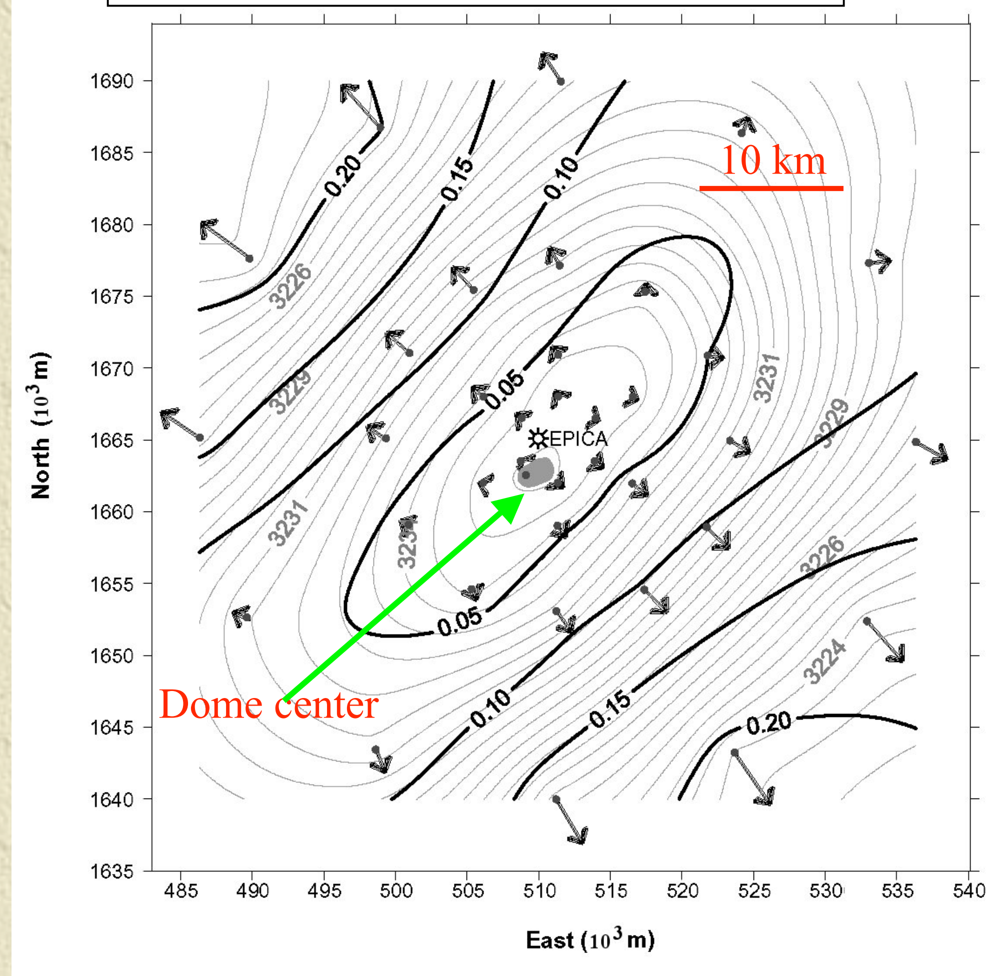
Images: Australian Antarctic Division

Ice motion: a manageable challenge



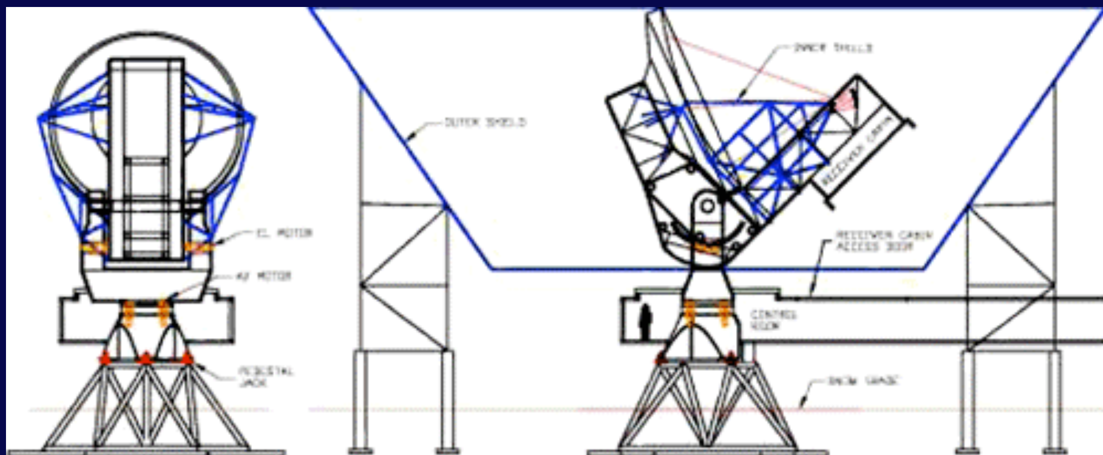
- Flow direction controlled by local slope
- Ice velocity increases with distance from Dome center
- V = 2 mm/yr on Dome
- ΔV = 1cm/km/yr
- **~0.1 um/hr/100m baseline change**
  - **regular baseline model updates**
- **~1cm relative motions for array elements - manageable**
- **Potential engineering challenge for delay lines**
  - **possible solution is OHANA-style multi-pass approach**

Ice motion in the Dome C area (m/yr)



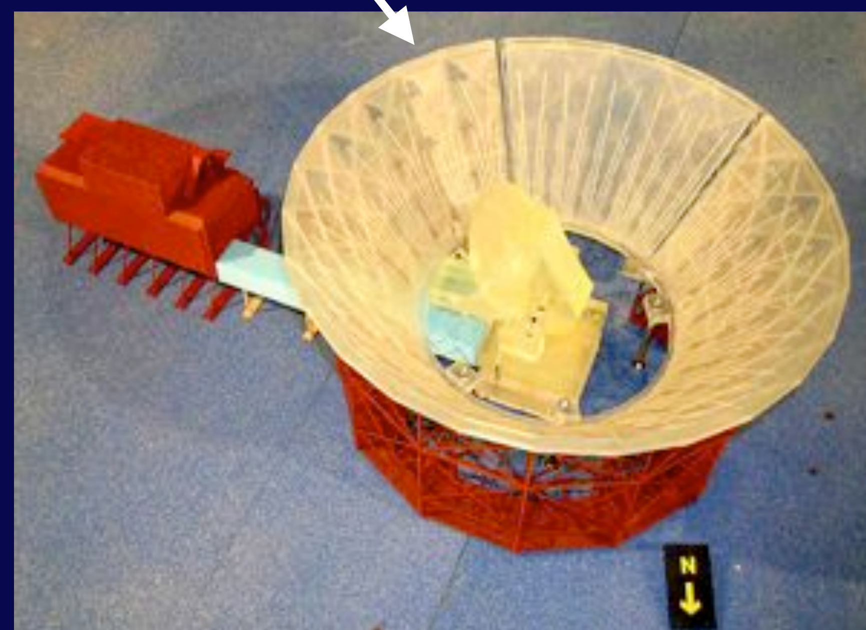
Vittuari et al. 2004, in press

South Pole 10m: 2006 – 2007



- 240 tonnes
- US$28m (comparable to cost of Atacama version)

Ground Shield



- Operation to l ≥200mm
- 10m off-axis Gregorian
- Pointing ~1.2”
- Surface ~20 mm rms
- Low noise (extensive shielding)
- Low offsets (telescope chopping)

Images: SPT team

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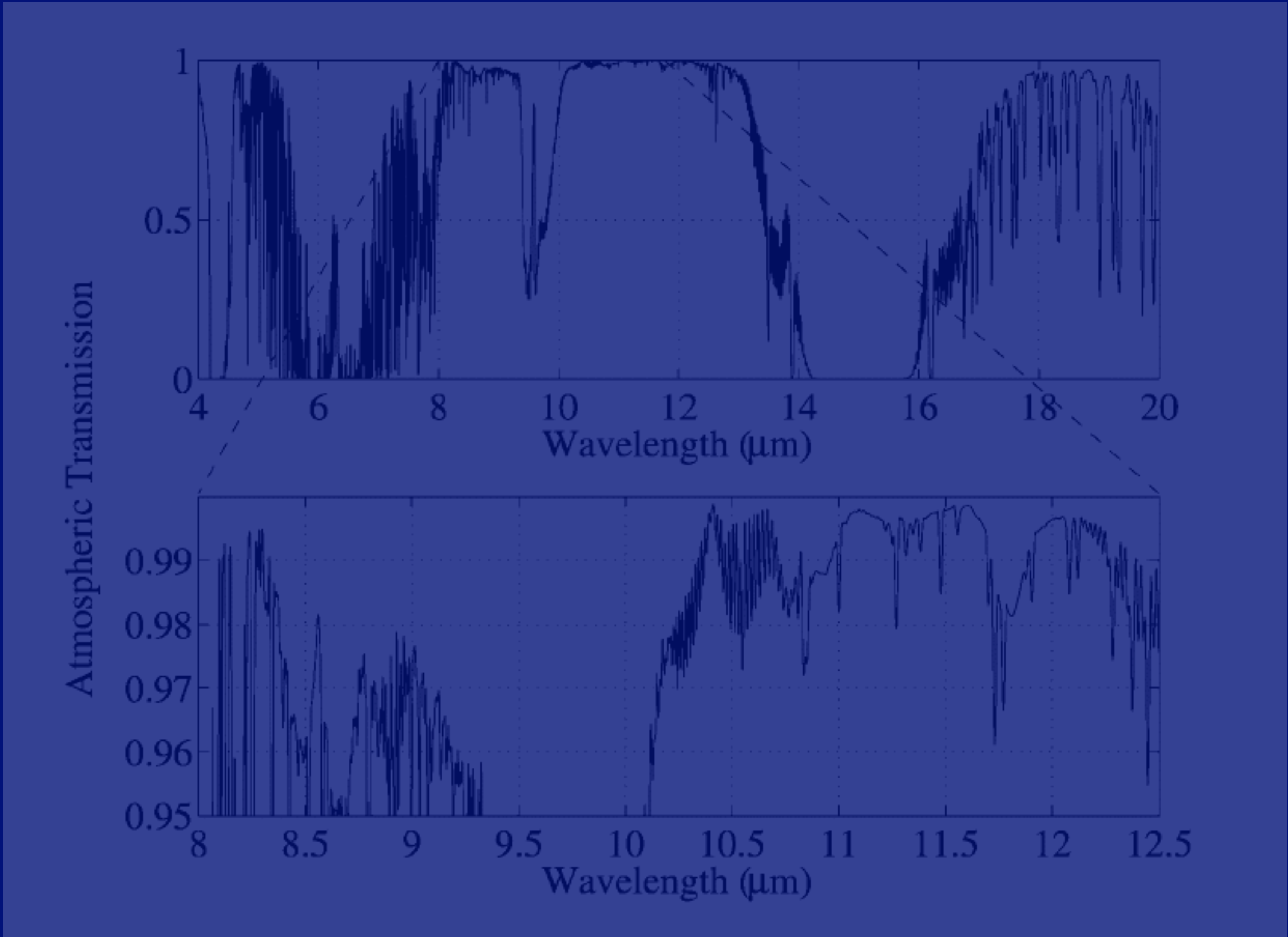
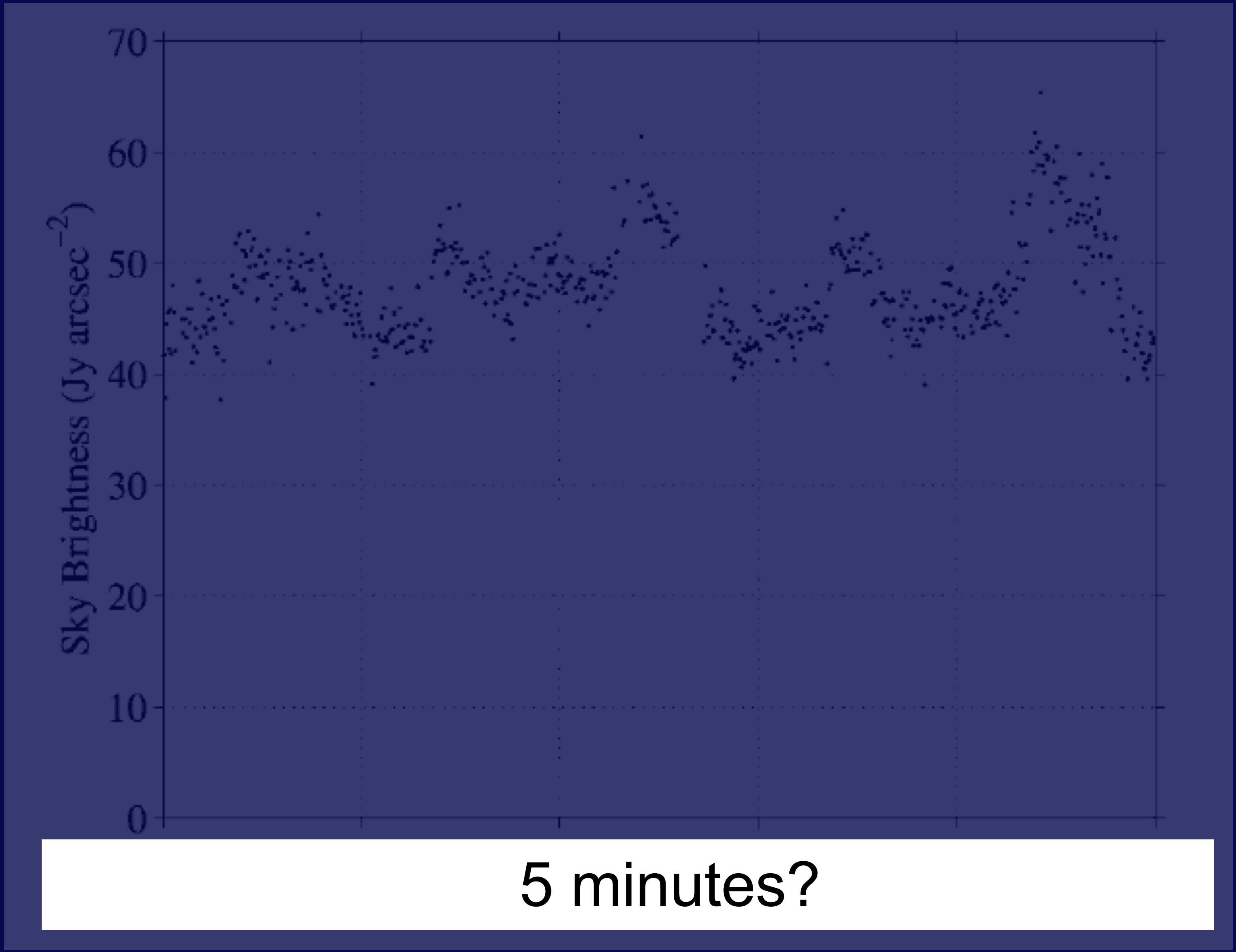


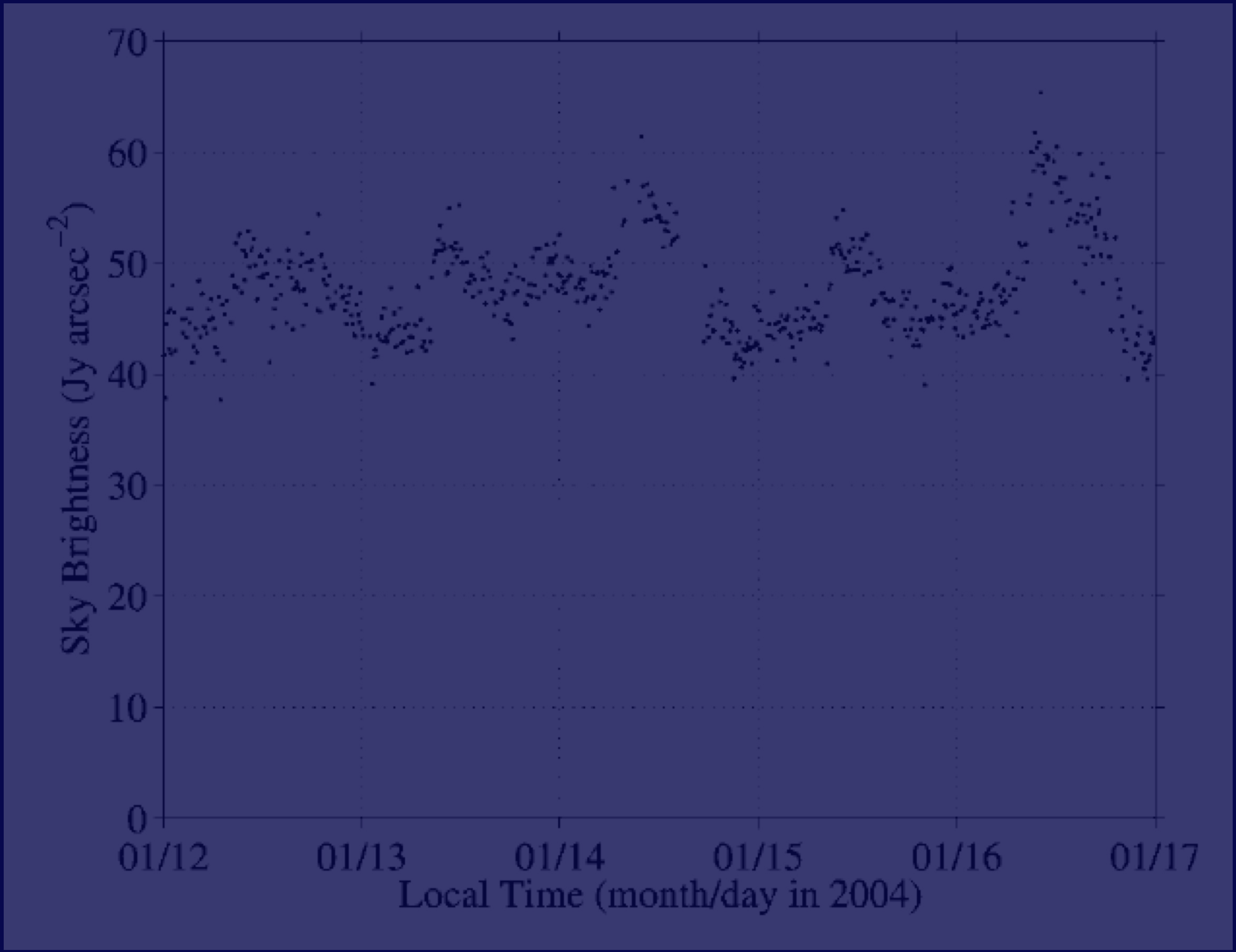
Atmospheric transmission, *summer time,* Dome C

Walden et al, PASP, 2005



Atmospheric stability, *summer time,* Dome C

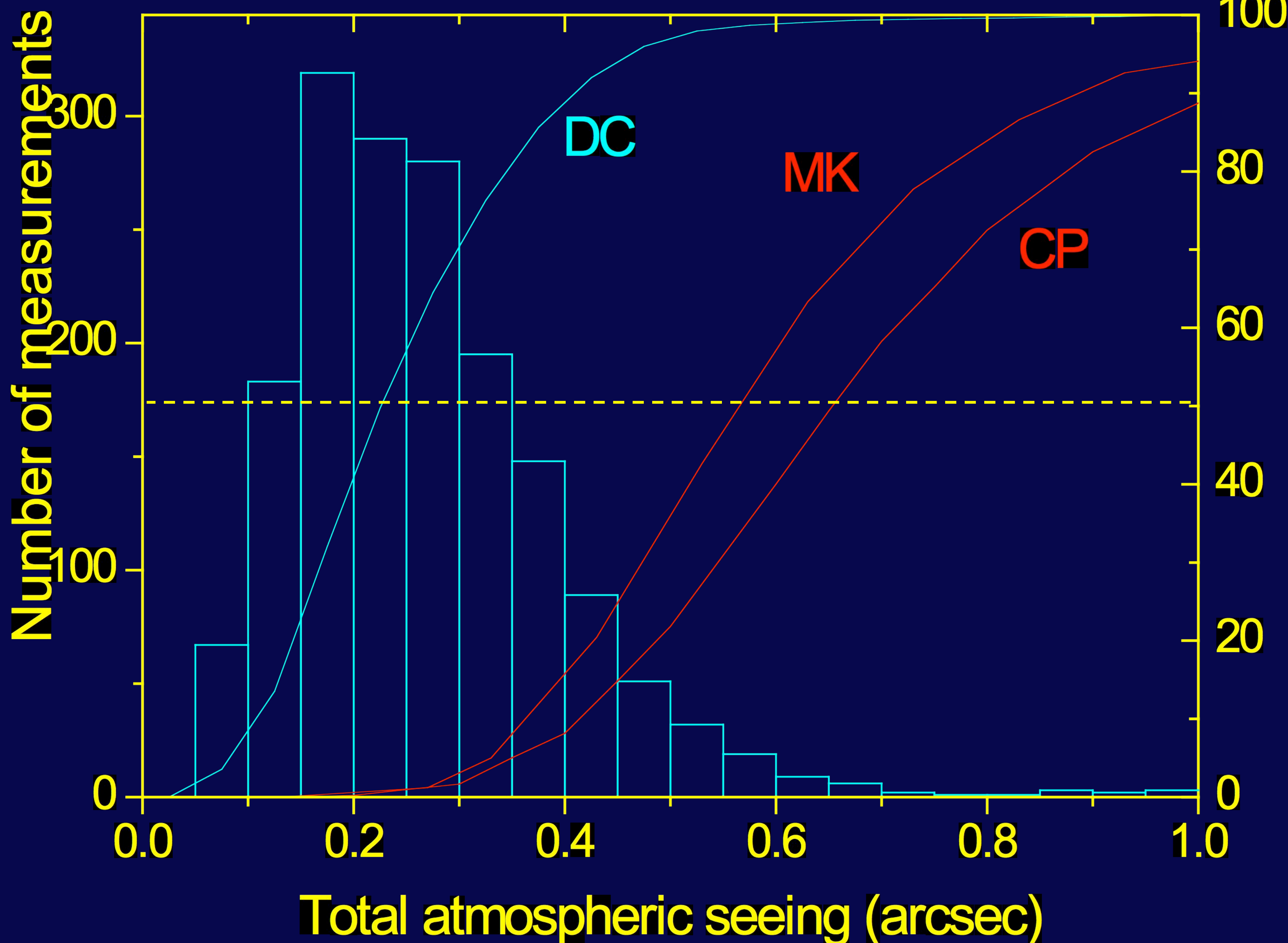
Walden et al, PASP, 2005



Atmospheric stability, *summer time,* Dome C

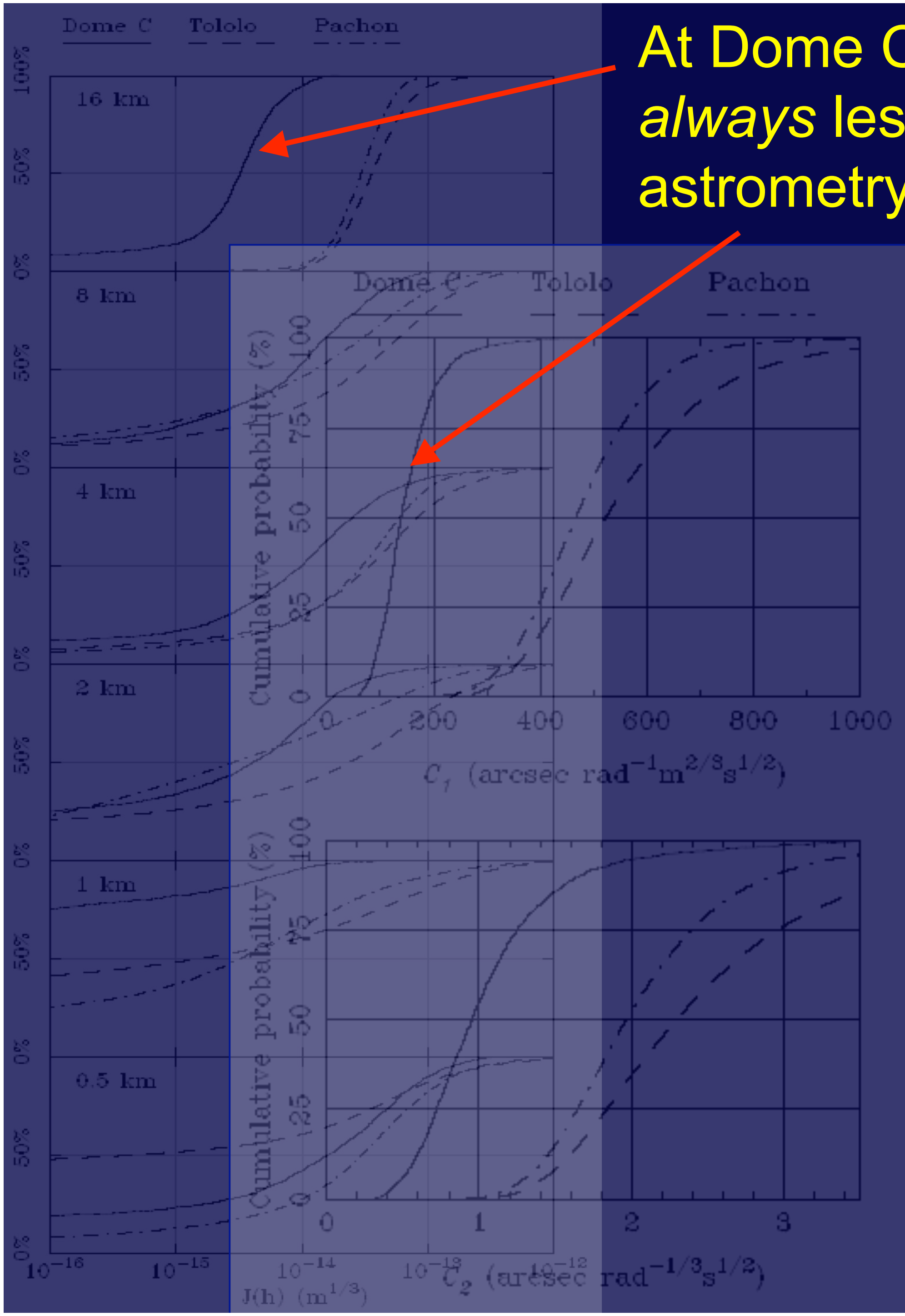
Walden et al, PASP, 2005

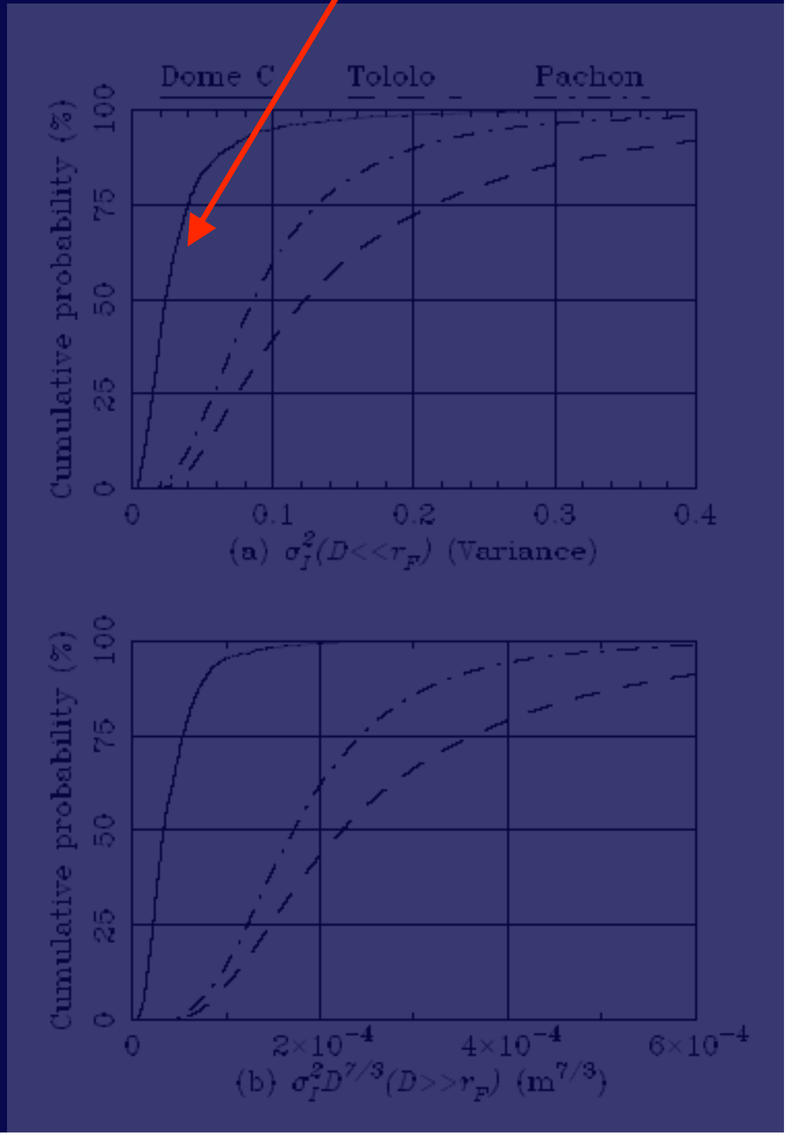
Lawrence, Ashley, Tokovinin, and Travouillon, *Nature,* **431,** 278, (2004)



At Dome C, the turbulence at 16 km is *always* less than in Chile, and so astrometry is better and scintillation is less

Kenyon et al 2006





Site testing: still need to know

- Isopistonic angle
- Outer scale
- Clear-sky statistics
- Temporal spectrum (not just coherence time)
- Surface layer height and variability
- Kolmogorov?
- Better statistics on all parameters!

Image: Paolo Calisse


Image: Patrik Kaufmann

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Estimates of the boundary layer thickness at Dome C

“Thin”. *Gillingham 1991,* Schwerdtfeger plus AWS

< 30 m *Lawrence et al 2004,* SODAR

> 20 m *Agabi et al 2006,* DIMM

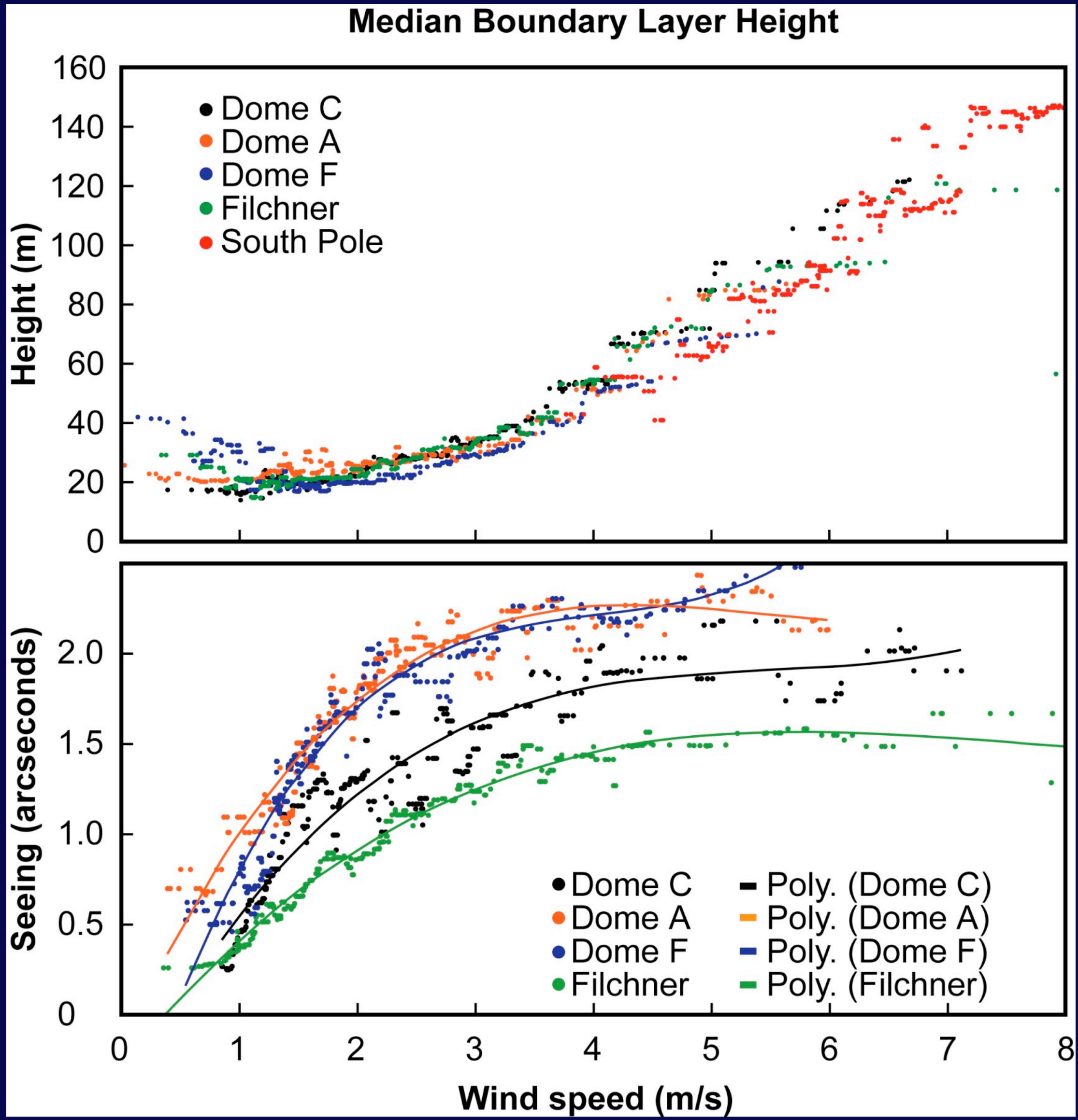
36 ± 19 m *Agabi et al 2006,* Balloon μthermal

27 m median *Swain & Gallee 2006,* modelling

Boundary Layer: height and seeing

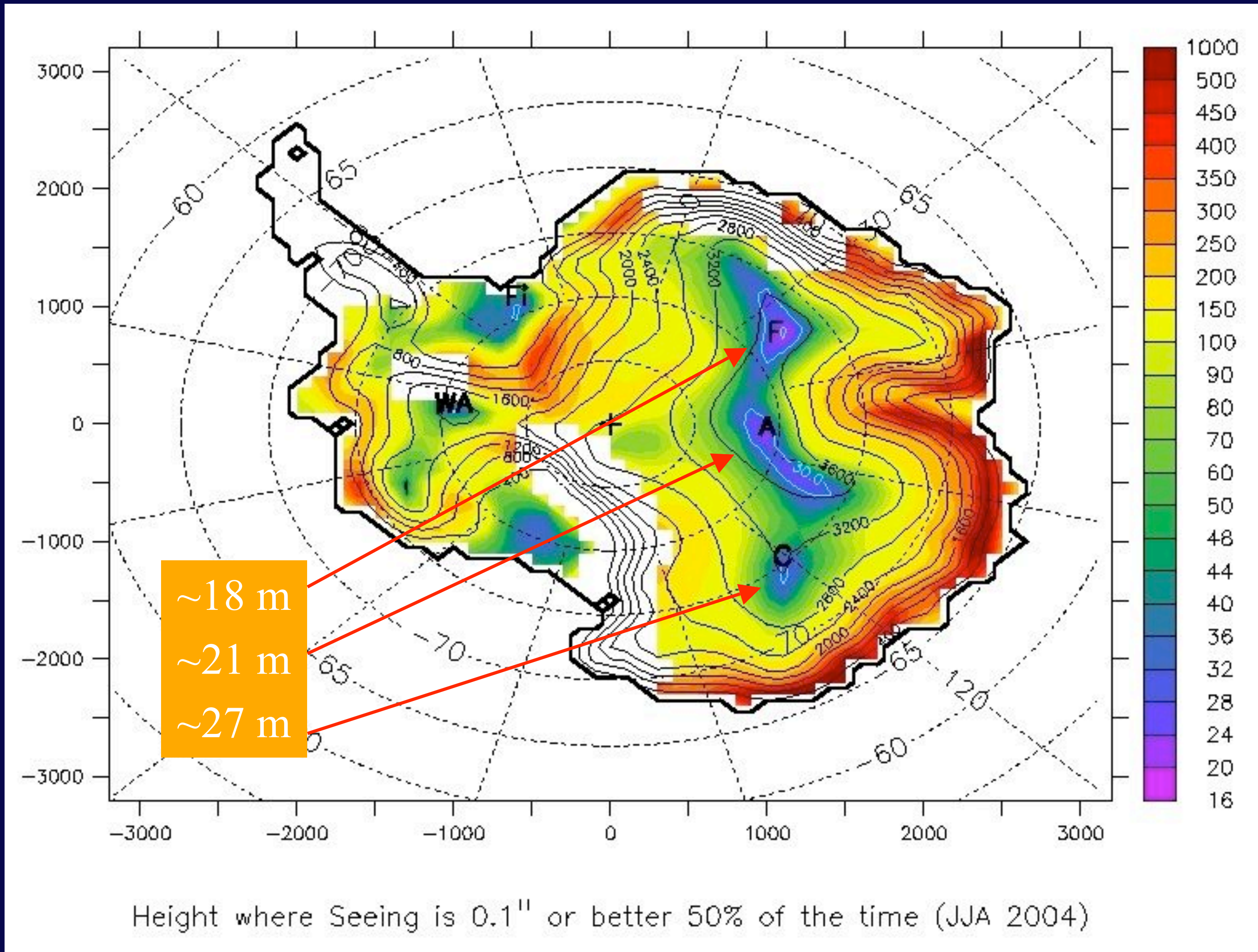
- Surface wind speed determines the boundary layer height and seeing.
- Seeing "saturates" above some wind speed
- Strong seeing everywhere because wind speed is high enough to put seeing in the "saturated" regime.
- The difference in the seeing/wind speed profile for Antarctic sites indicates the Dome A/F inversion is stronger.
- Strong inversion implies more "clear sky" time.

Dome A/F will have fewer clouds than Dome C.



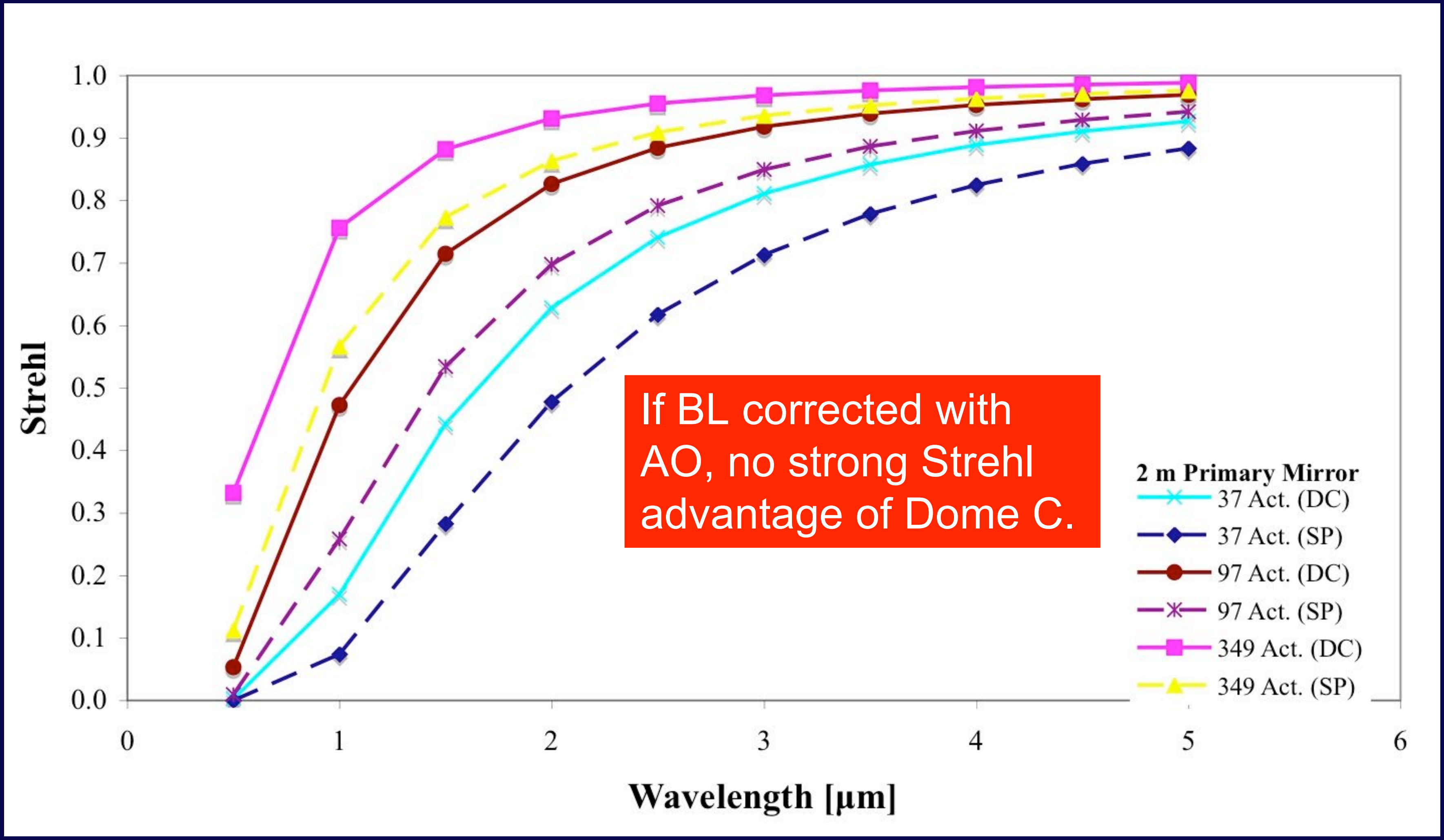
Swain & Gallee, 2006

Elevated Telescopes



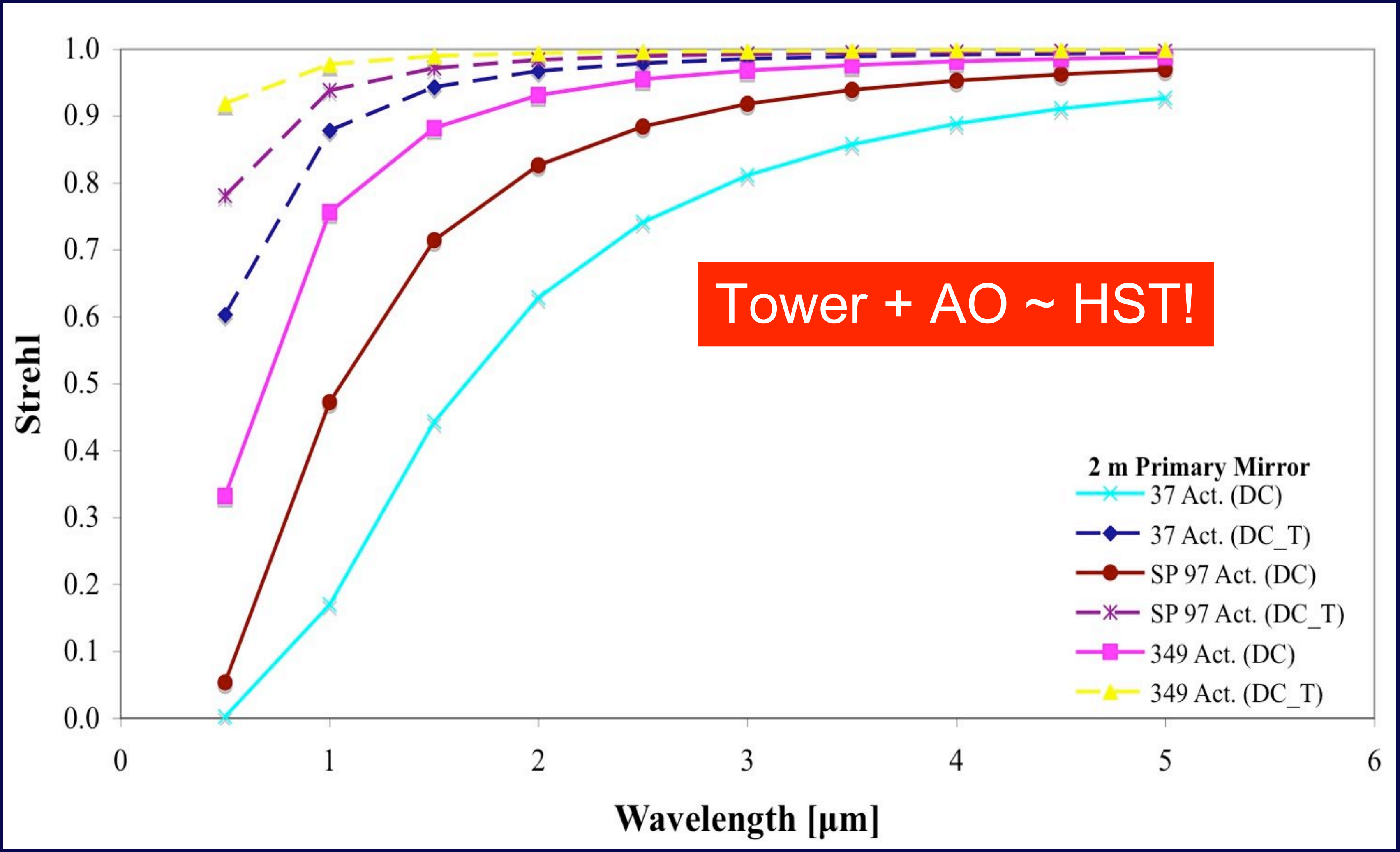
Swain & Gallee, 2006

Boundary layer AO correction at South Pole and Dome C



Swain et al, 2006

Dome C: Tower + AO



Swain et al, 2006

Deflection under maximum wind gusts at Dome C is less than 25 milli arcsec (Lanford et al 2006)

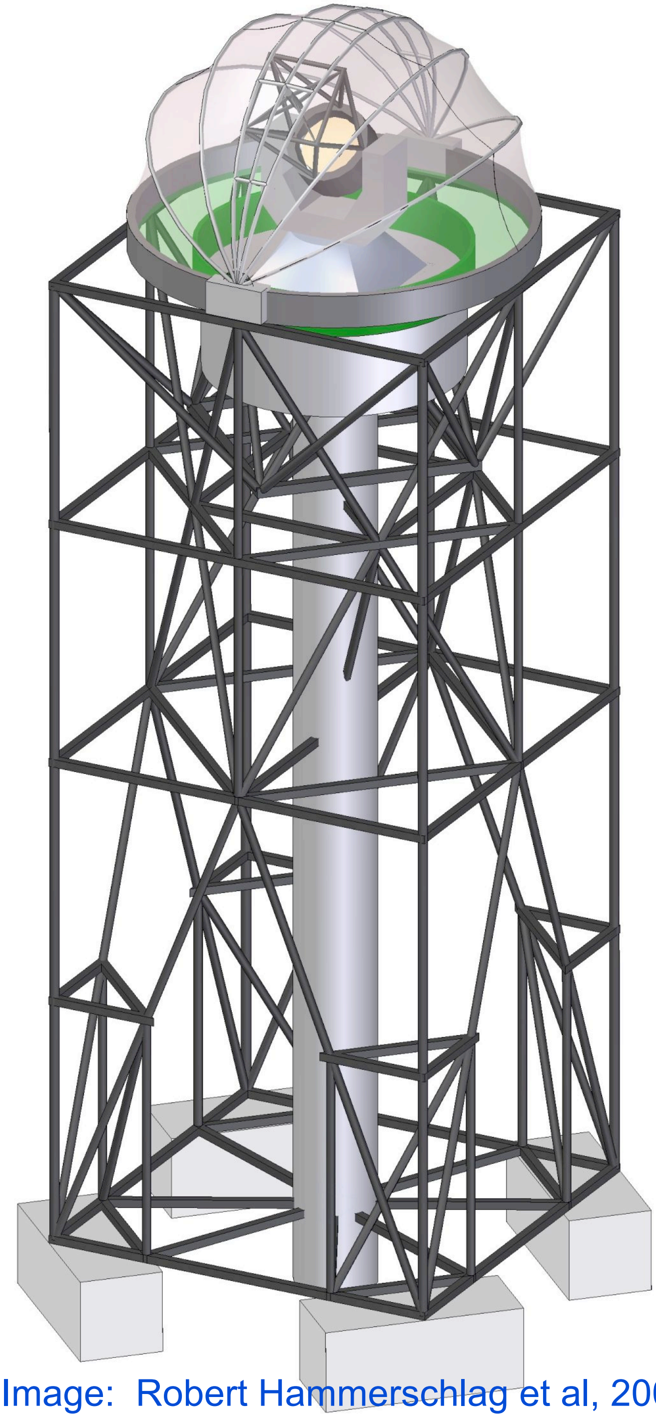


Image: Robert Hammerschlag et al, 2006

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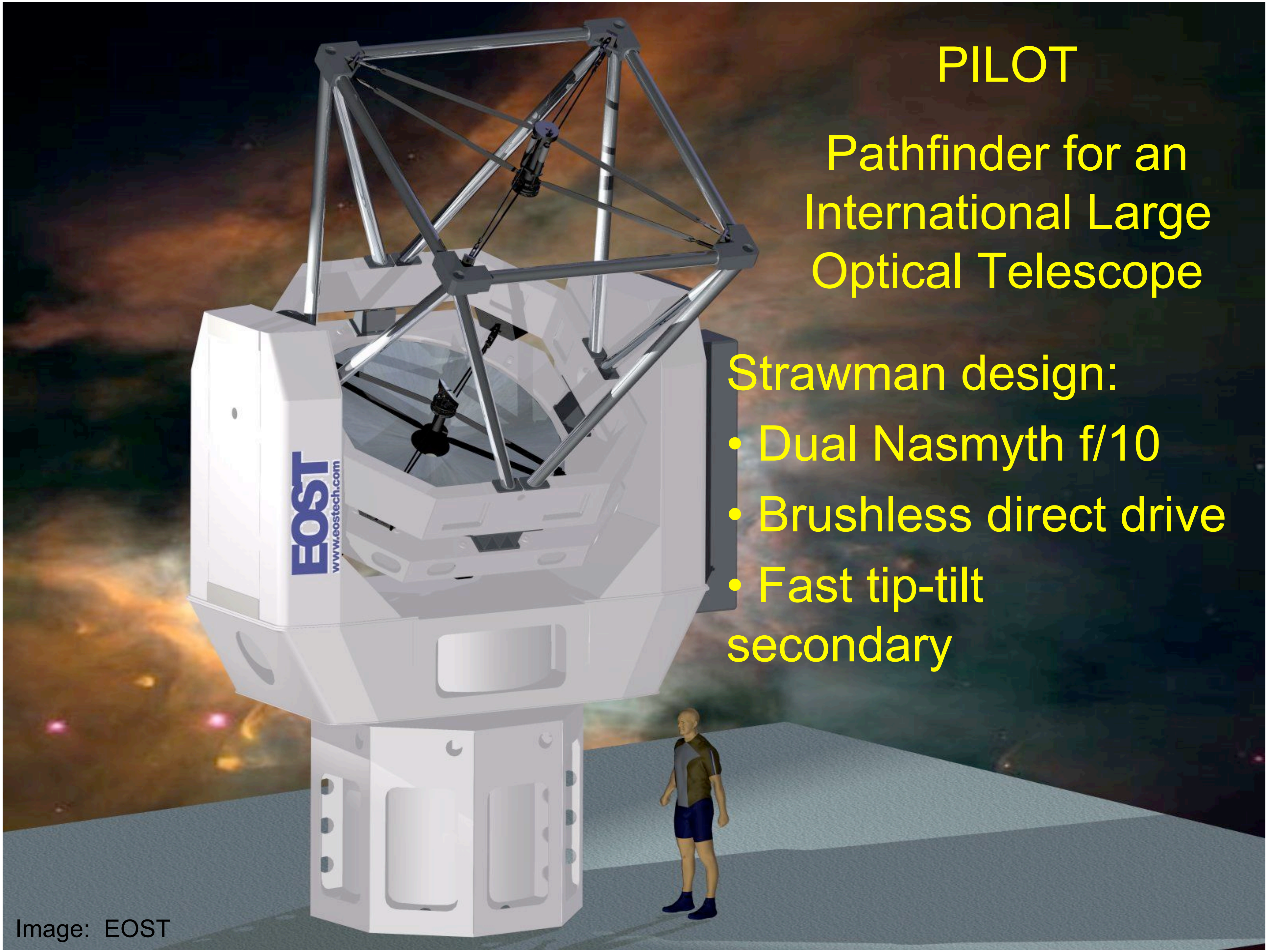
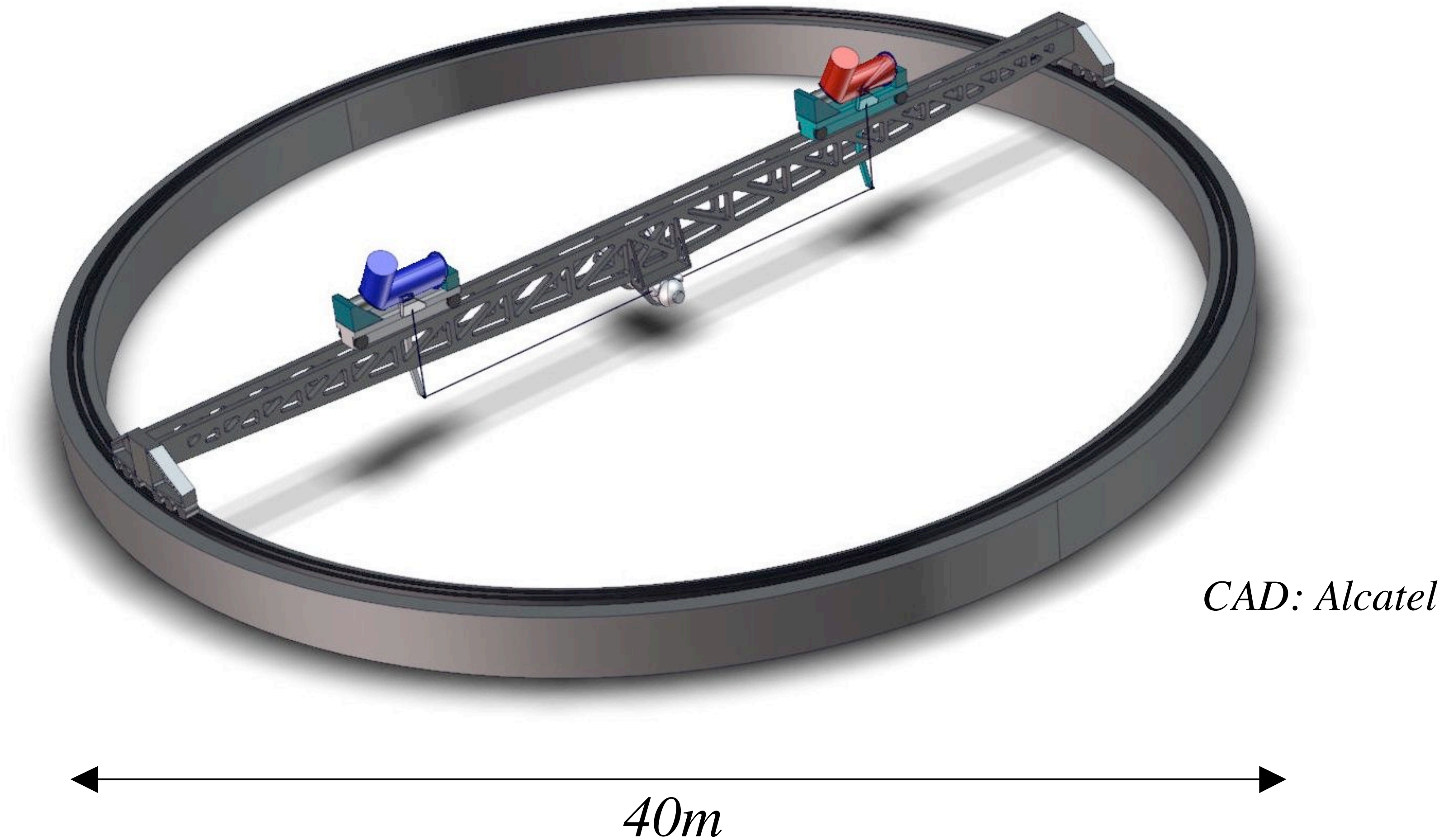

PILOT
Pathfinder for an International Large Optical Telescope
Strawman design:
• Dual Nasmyth f/10
• Brushless direct drive
• Fast tip-tilt secondary
EOST
www.eostech.com
Image: EOST

Can PILOT act as a pathfinder for future telescopes (including interferometers), *and* do good science?

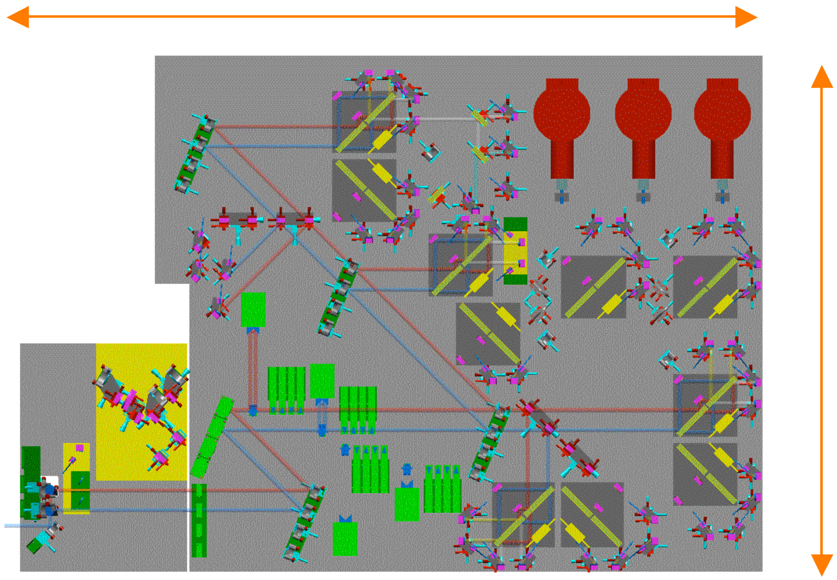
Image: John Storey

A possible ALADDIN concept

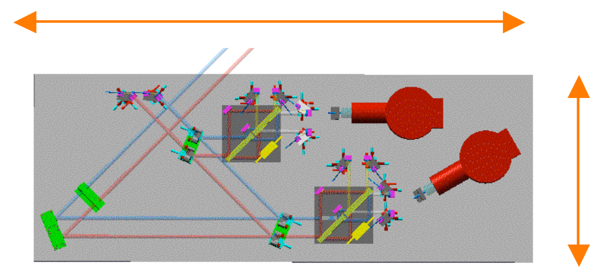
(for details see poster #13)



Instrument comparison



GENIE



ALADDIN

- If ALADDIN is not above the ground layer, add either:
  - An AO system for 97% Strehl in the L band
  - Or a 1kHz intensity control loop

Performance comparison ALADDIN vs. GENIE

- Methodology:
  - Use same end-to-end simulation software (den Hartog & Absil 2004)
  - Appropriate instrumental and atmospheric model inputs
- Performance gain due mostly to:
  - Lower loop frequencies
    - Fringe tracking 4kHz
    - Tip-tilt 1kHz
  - Better optical throughput
  - Lower, more stable background
  - Baseline optimization
- *Calibration gains not included*

5σ detectivity of exozodiacal light in 1800s integration time (in multiple of solar zodiacal light units)

Source	GENIE 2 x 1.8m	GENIE 2 x 8m	ALADDIN 2 x 1m
KOV @ 5pc	110	215	**38**
G5V @ 10pc	147	56	**26**
GOV @ 20pc	339	37	**20**
GOV @ 30pc	714	48	**23**

Absil et al., in preparation

Future ideas

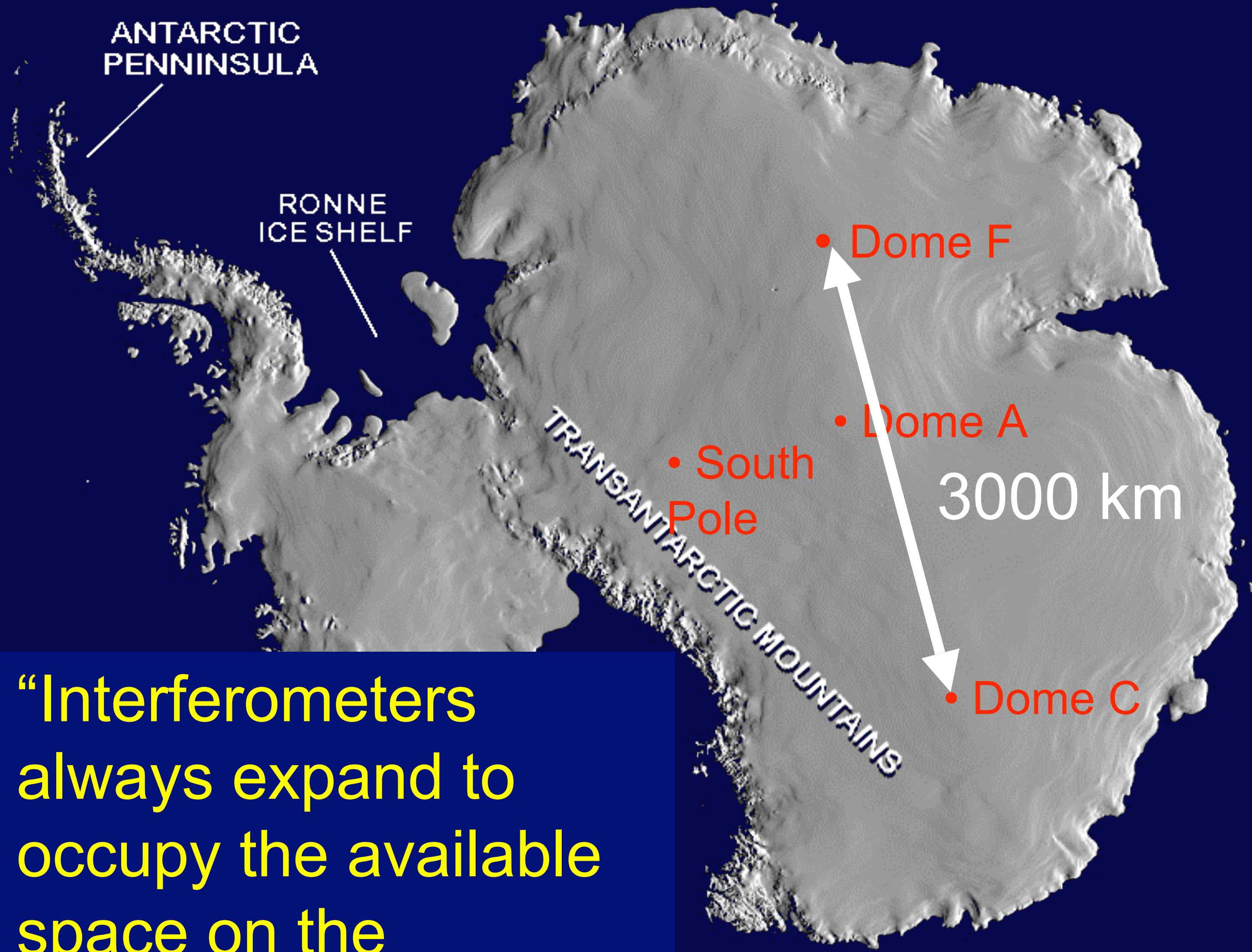
- Overwhelmingly Large Array (OLA)
  - 12 x 12 m telescopes @ $700m

↓

- Cold Overwhelmingly Large Array (COLA)
  - 12 x 2m telescopes at $60m
  - Comparable performance
  - 36x larger instantaneous FOV (single mode)
  - Broader wavelength coverage

Image: Paolo Calisse

And a final word from Jamie Lloyd



"Interferometers always expand to occupy the available space on the mountain top."

USGS image


The end
Images: Michael Ashley & EOST