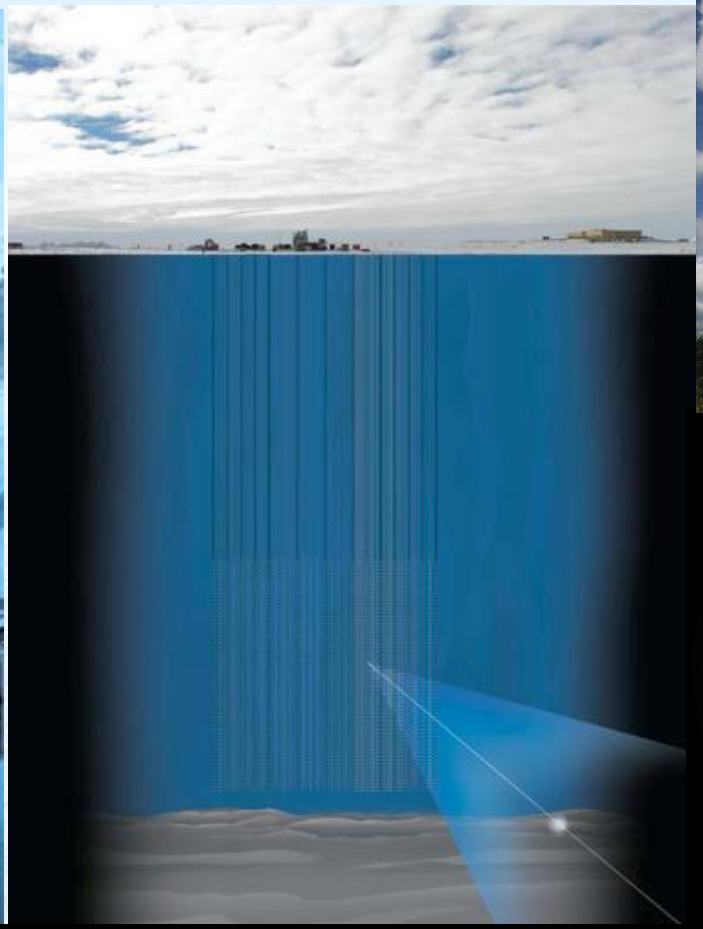
Synergies in ice: Astrophysicists come down to Earth

Ryan Bay
University of California, Berkeley

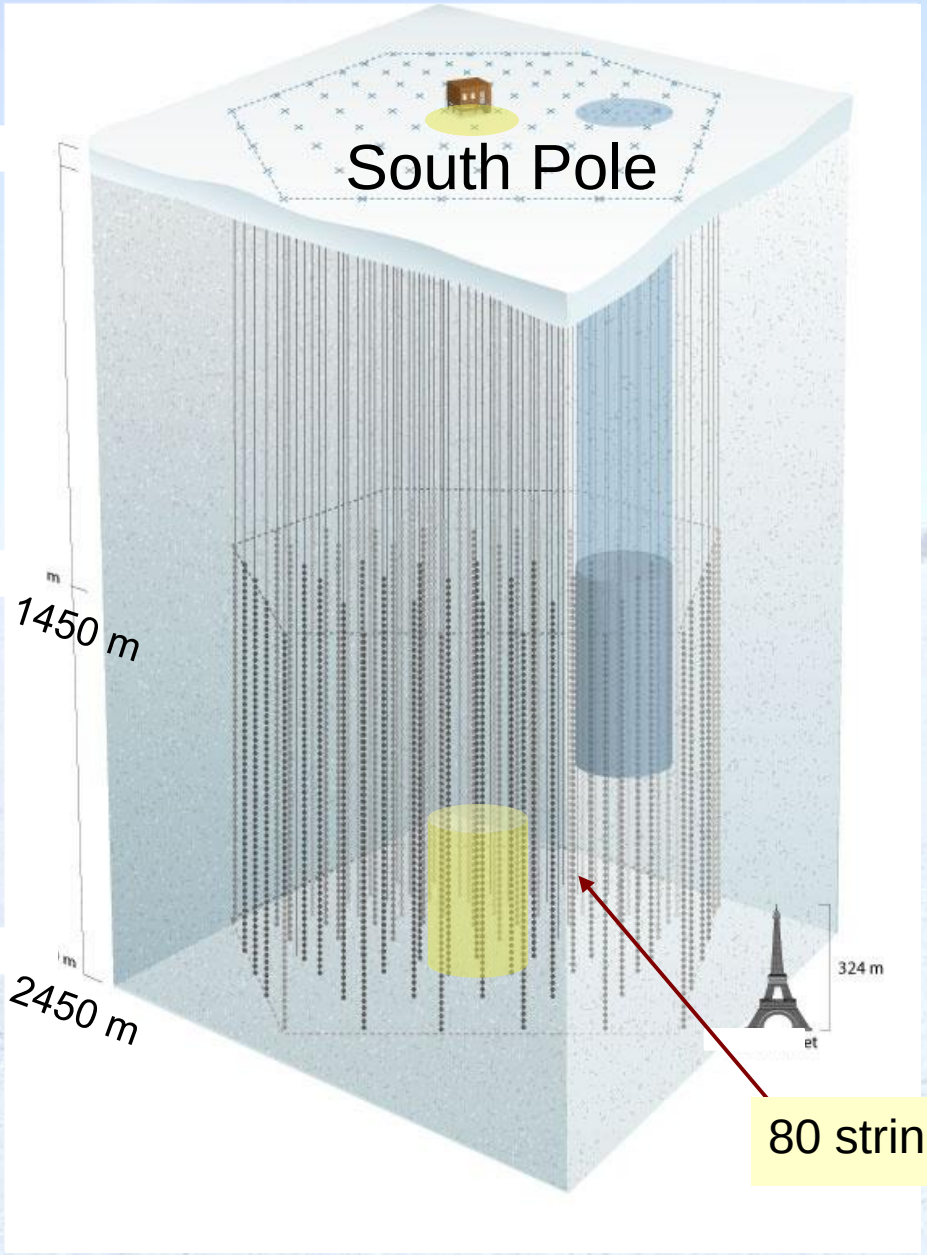


The IceCube Collaboration

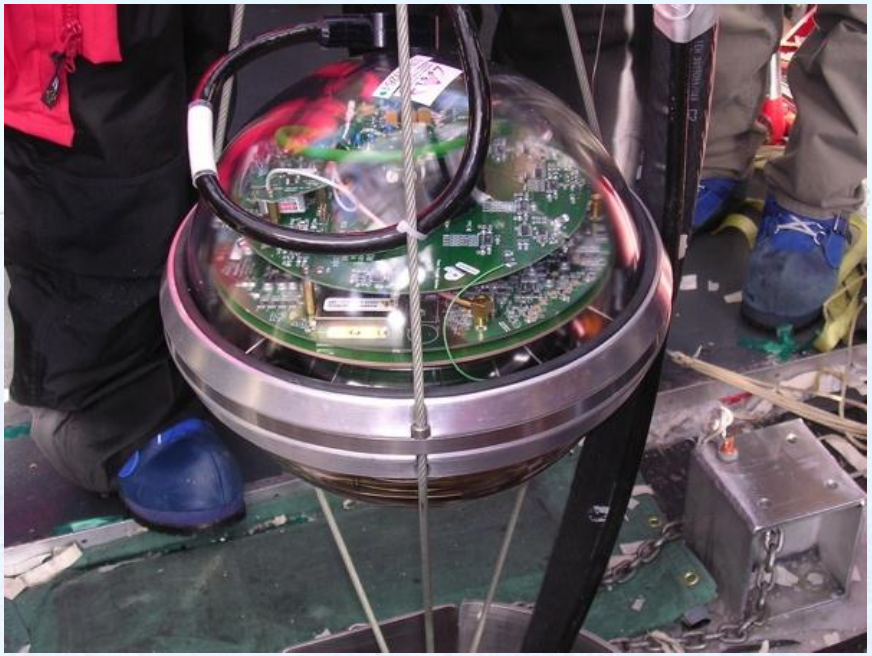
International Funding Agencies

Fonds de la Recherche Scientifique (FRS-FNRS)
Fonds Wetenschappelijk Onderzoek-Vlaanderen (FWO-Vlaanderen)
Federal Ministry of Education & Research (BMBF)
German Research Foundation (DFG)
Deutsches Elektronen-Synchrotron (DESY)
Knut and Alice Wallenberg Foundation
Swedish Polar Research Secretariat
The Swedish Research Council (VR)
University of Wisconsin Alumni Research Foundation (WARF)
US National Science Foundation (NSF)

IceCube neutrino telescope

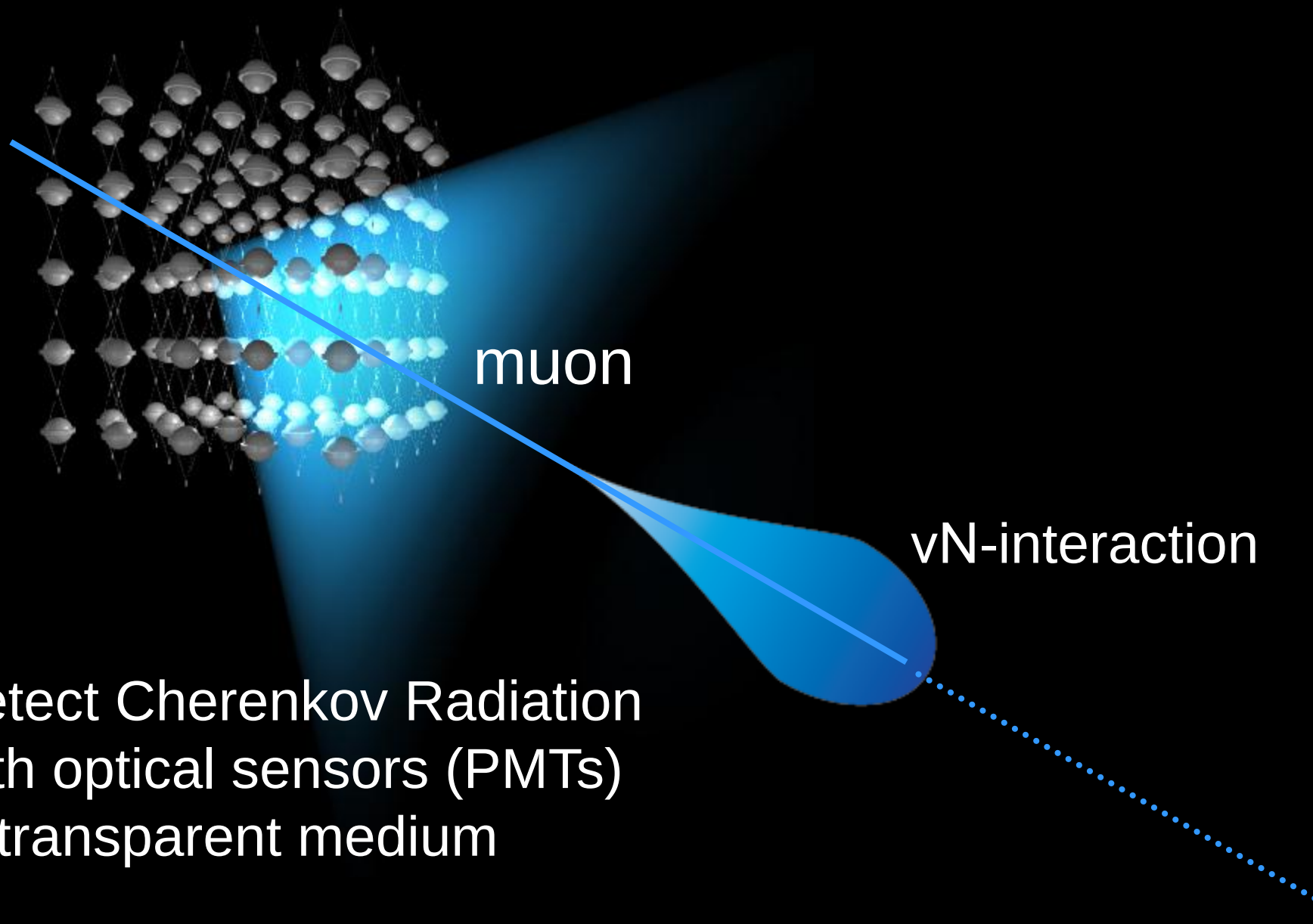


Digital
Optical
Module



80 strings × 60 DOMs each

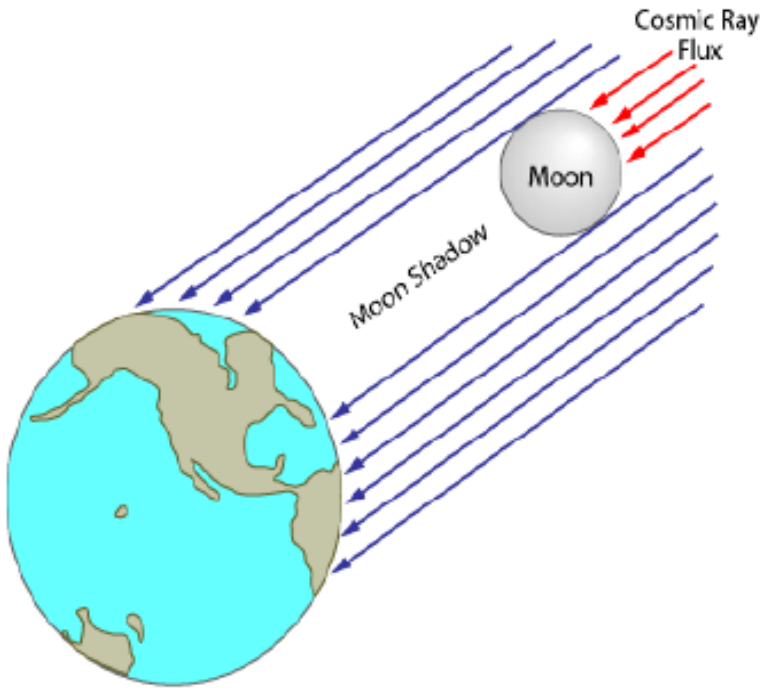
Neutrino Detection



Detect Cherenkov Radiation
with optical sensors (PMTs)
in transparent medium

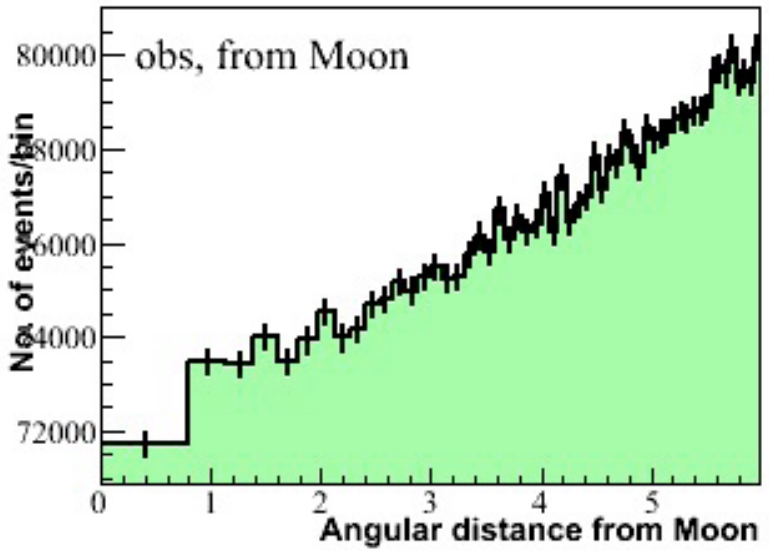
Lunar Shadow “Vision Test”

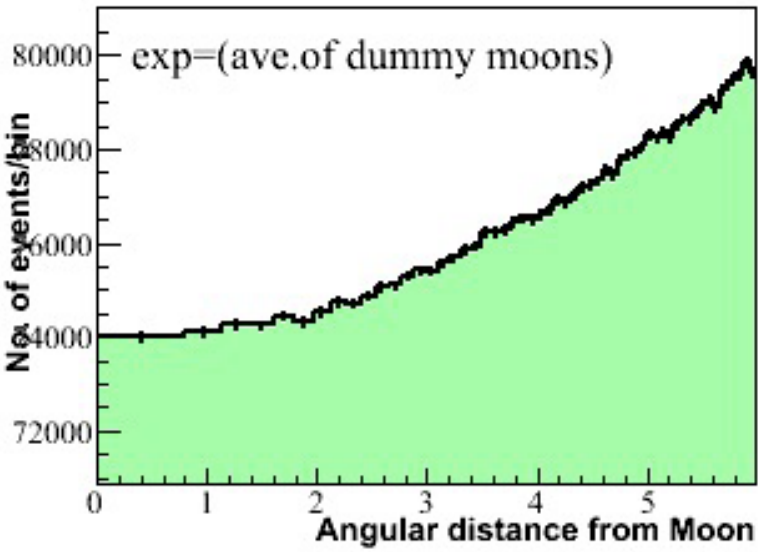
• Cosmic rays blocked by the moon should lead to a point-like deficit in the distribution of down-going muons in the detector.

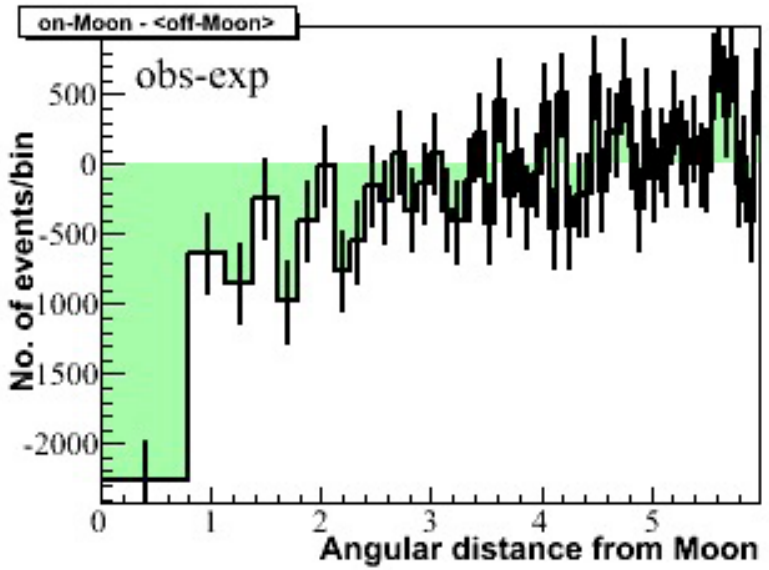


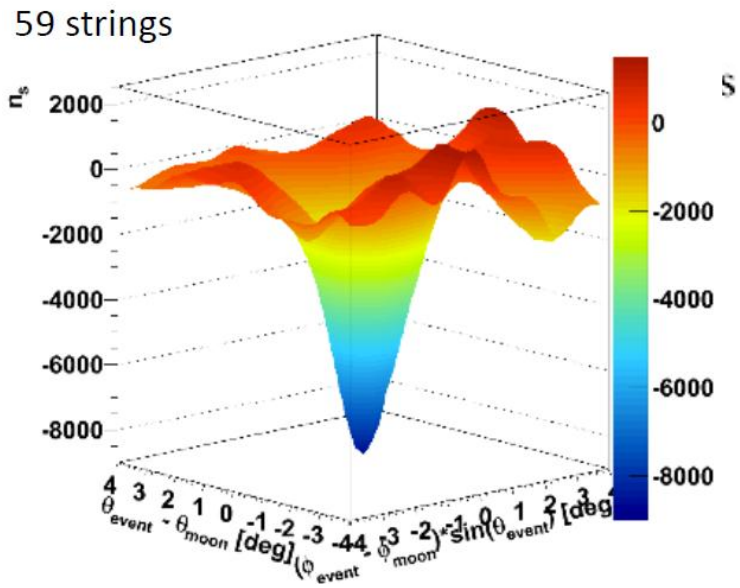
Need high statistics and good angular resolution!

Lunar Shadow “Vision Test”



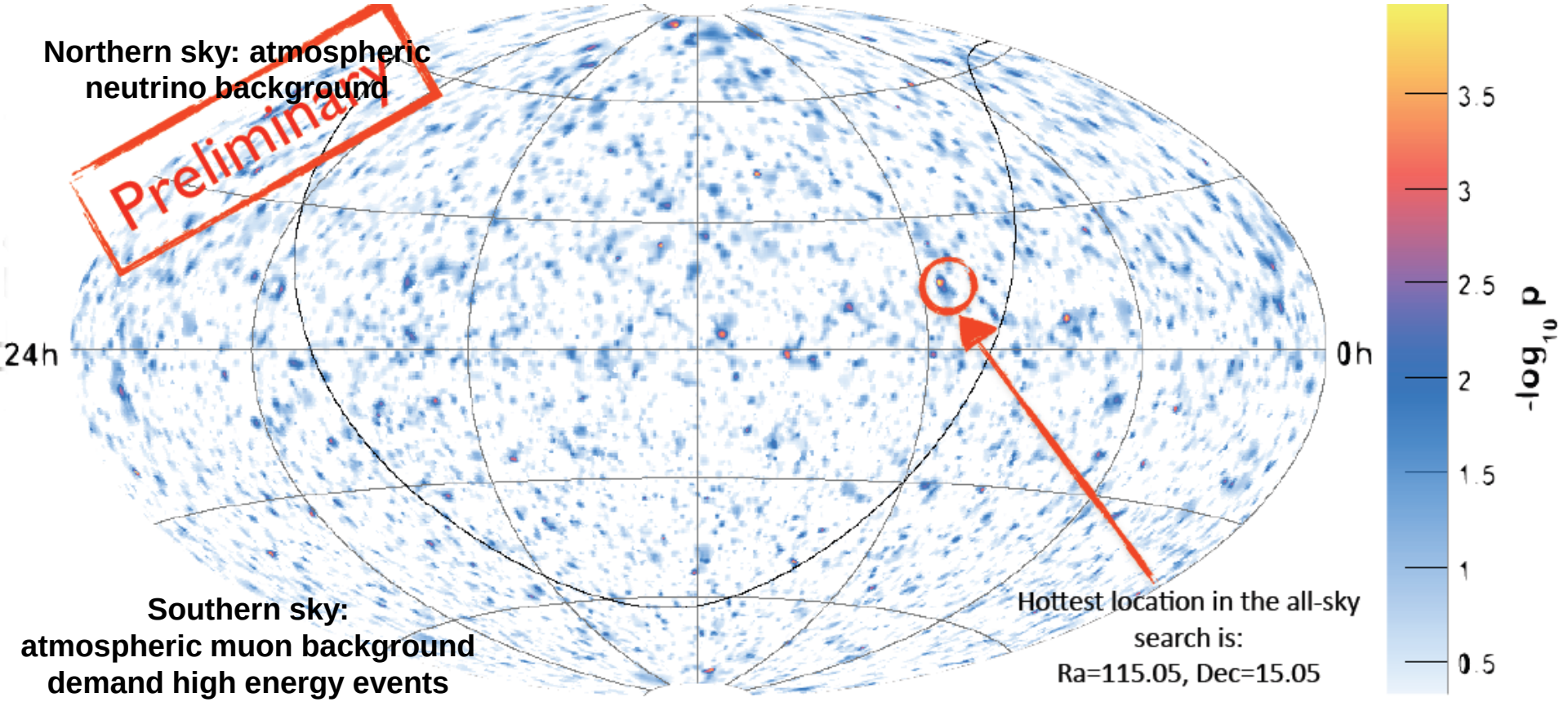






Pointing accuracy is confirmed!

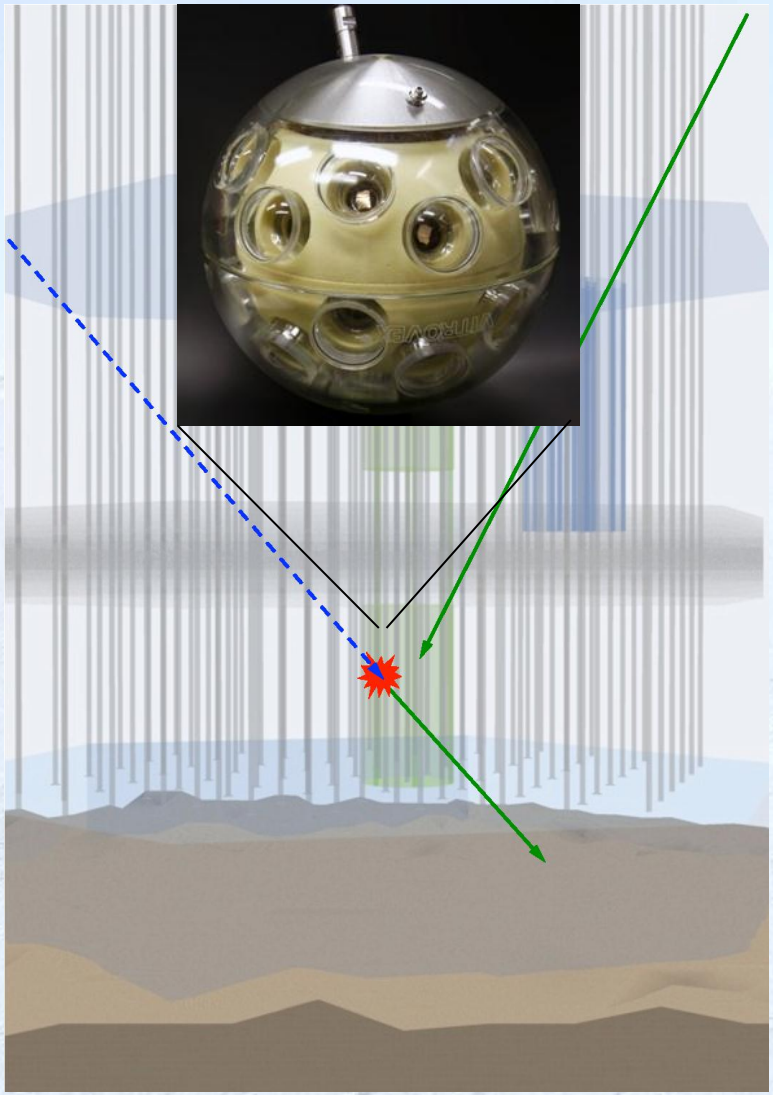
Full-sky point source search



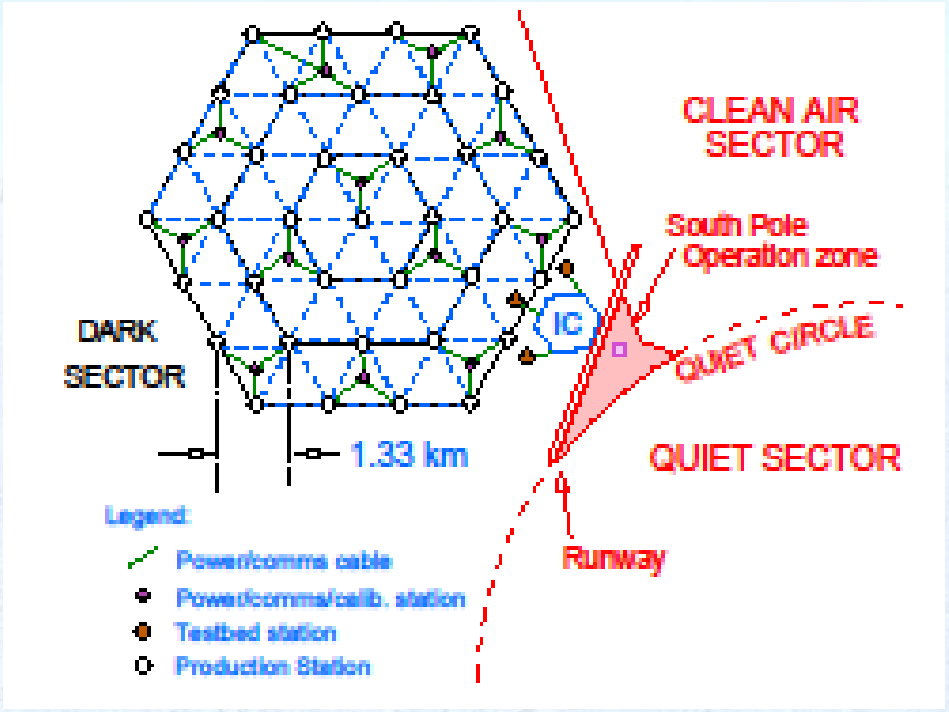
No significant cosmic neutrino sources, yet…

Low-energy and ultra-high-energy extensions of IceCube

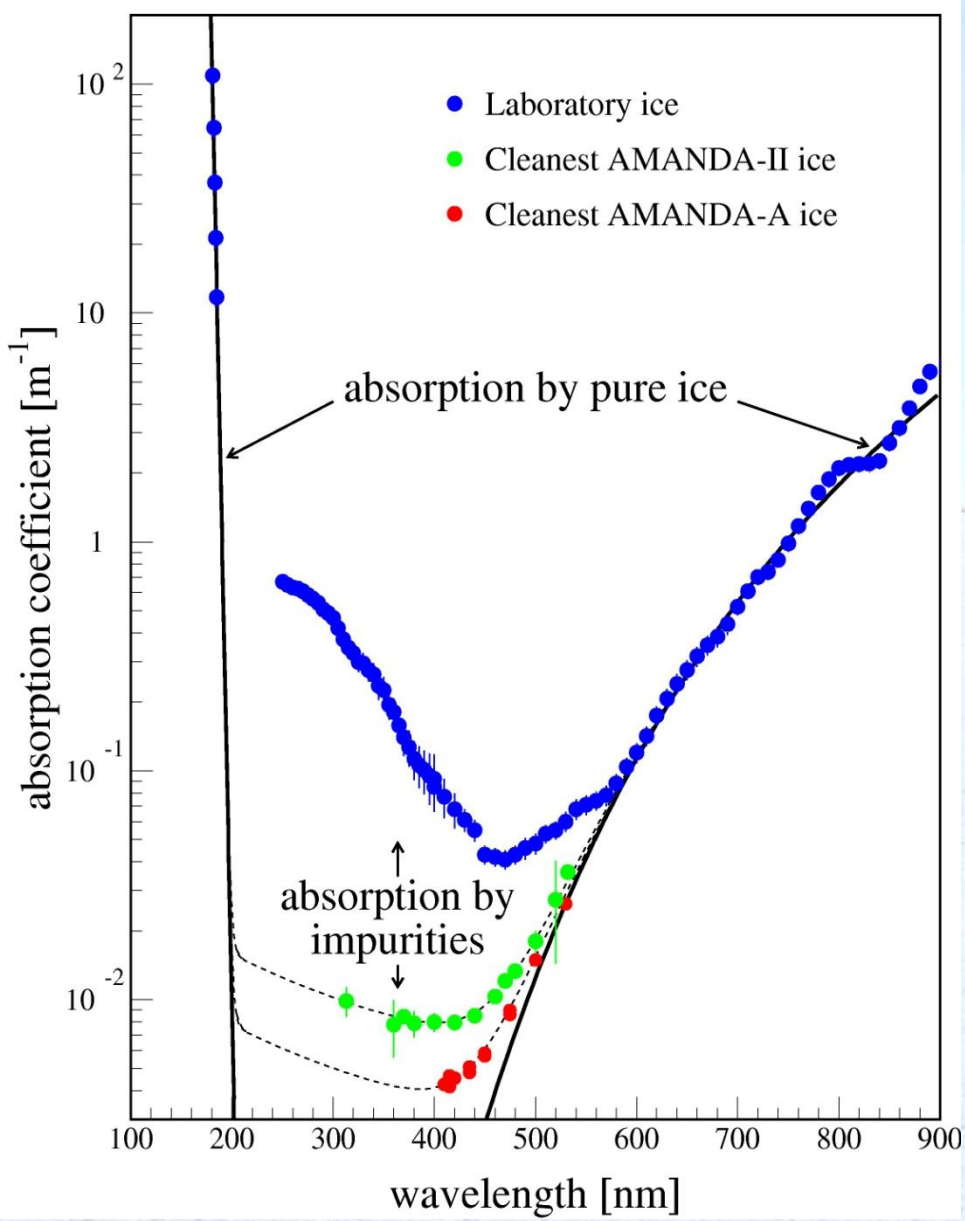
Low energy core



Askaryan Radio Array



Why South Pole ice?



Antarctic Ice is
the most transparent
natural solid known

Average optical ice parameters:

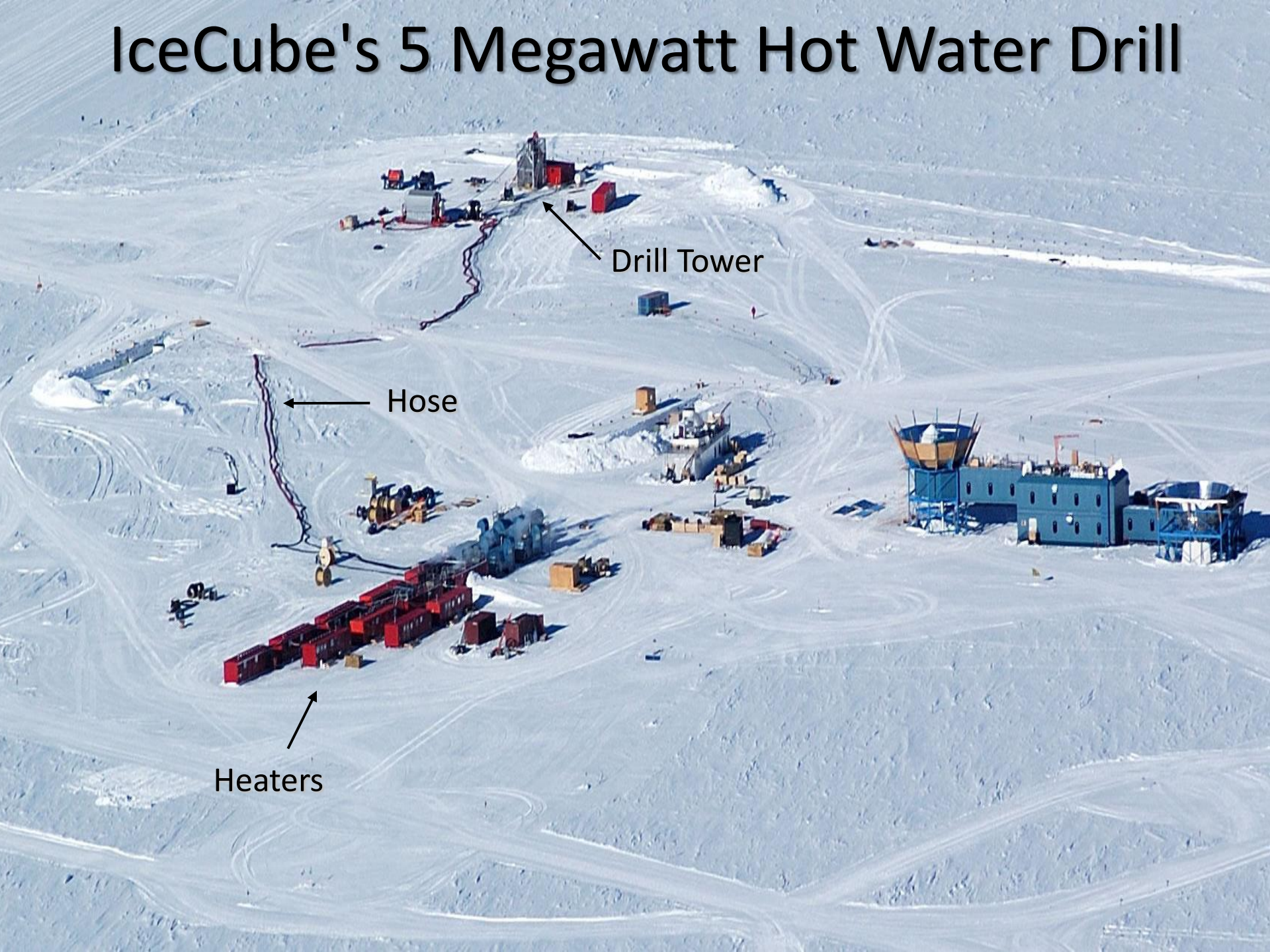
ℓ_{abs} ~ 110 m @ 400 nm
(*better than ocean*)

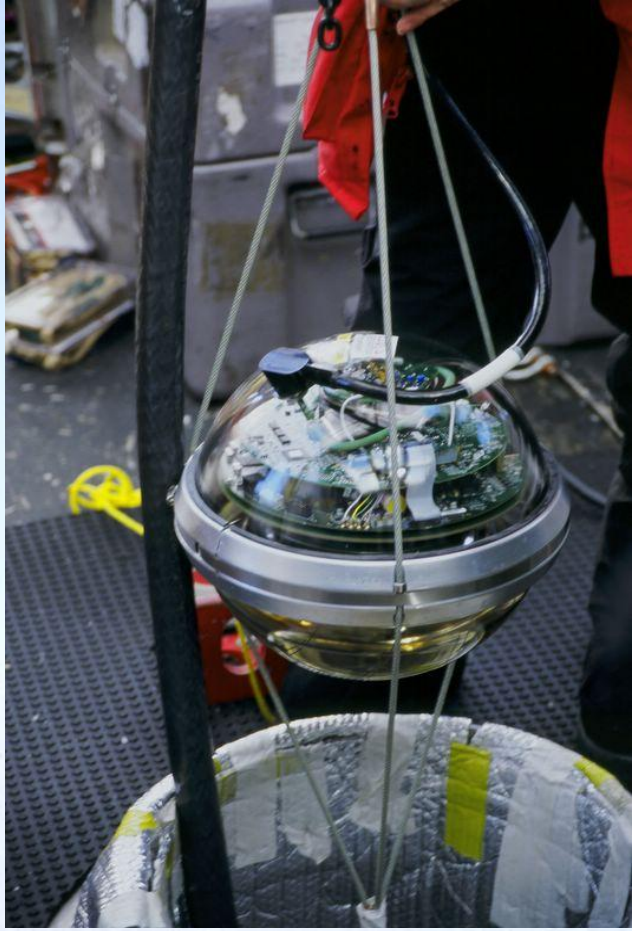
ℓ_{scat} ~ 20 m @ 400 nm
(*worse than ocean*)

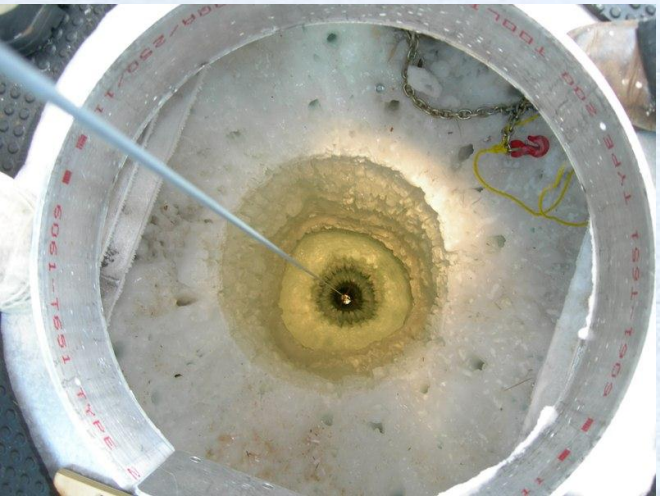
New South Pole station

… not always easy

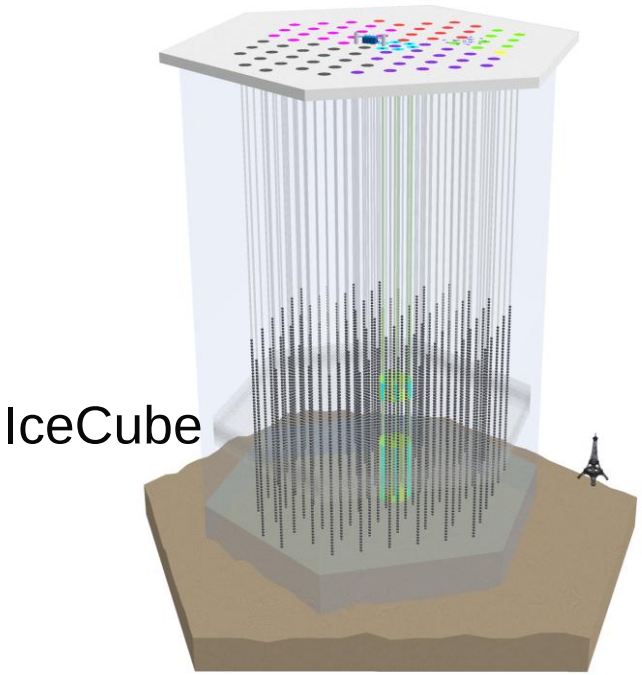
IceCube's 5 Megawatt Hot Water Drill





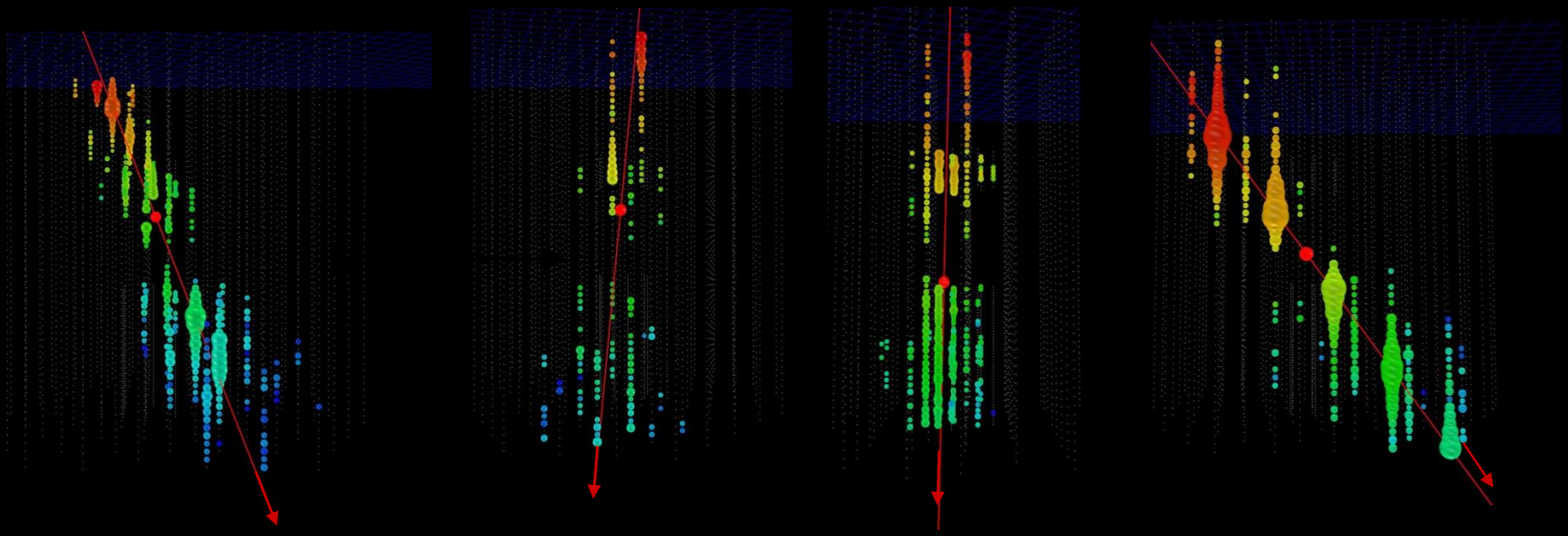


Enhanced Hot Water Drill

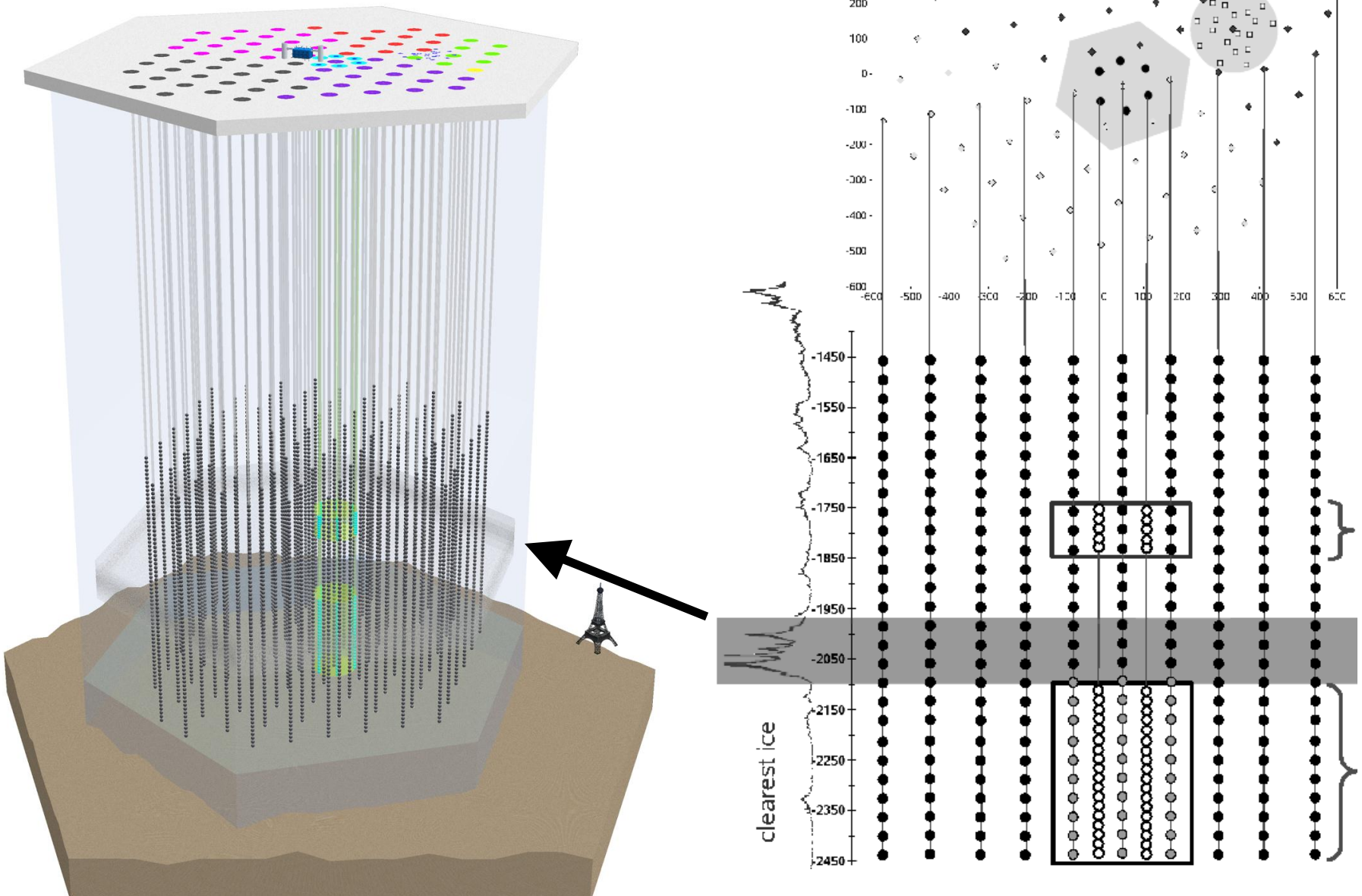


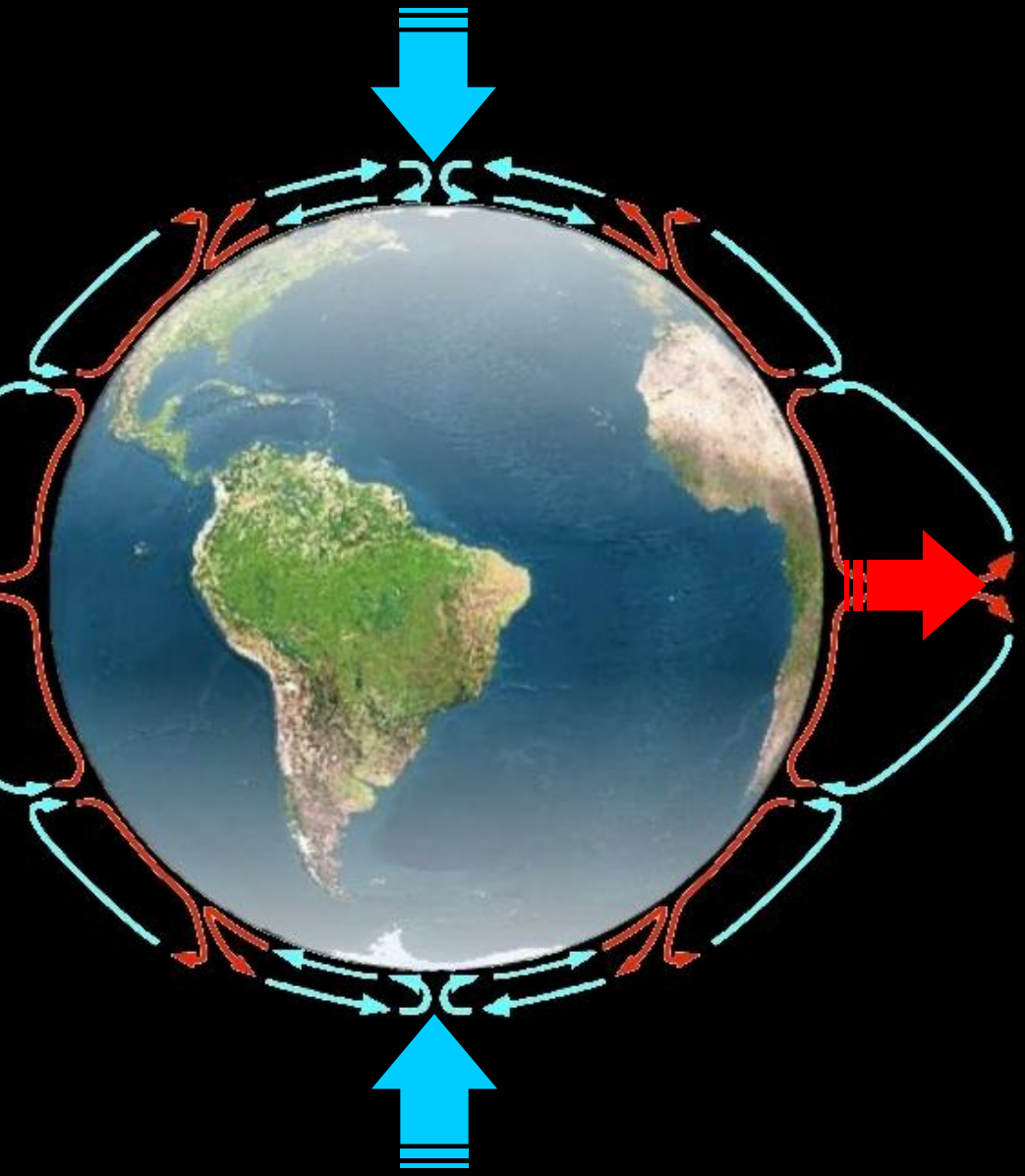
- Personnel: 30 drillers
- Power: 5 MW
- Holes: 0.5 × 2500 m × 30 hr
- Rate: <48 h per hole
- Good safety record

A few bright IceCube events



The IceCube "Dust Layer"





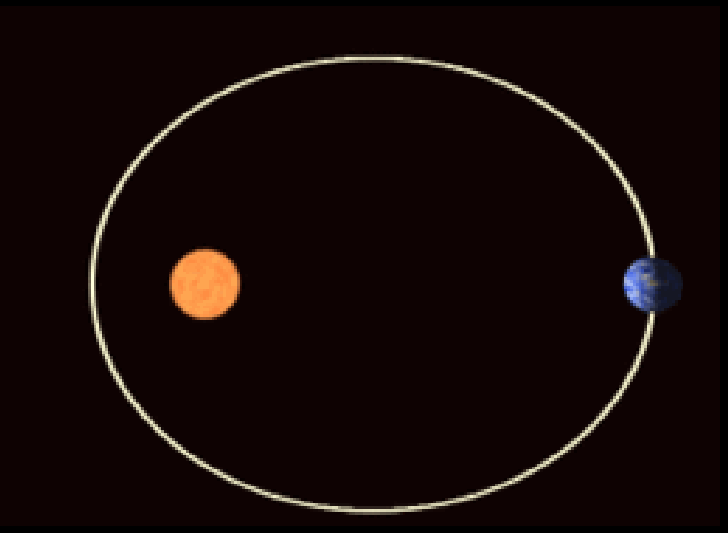
Dustier ice
<u>during cold climate</u>

Greater dust
supply

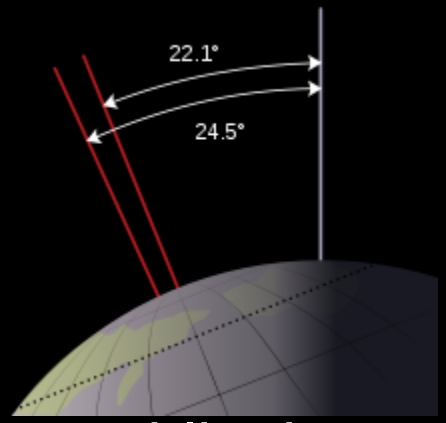
+

More vigorous
circulation, storms,
wind

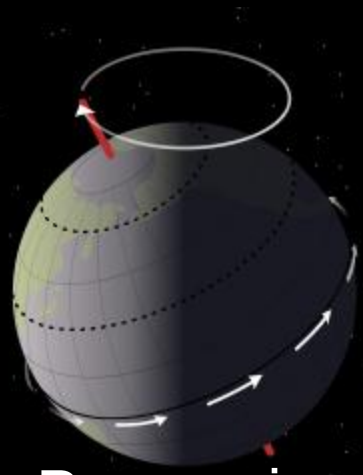
Milankovitch theory of glacial cycles



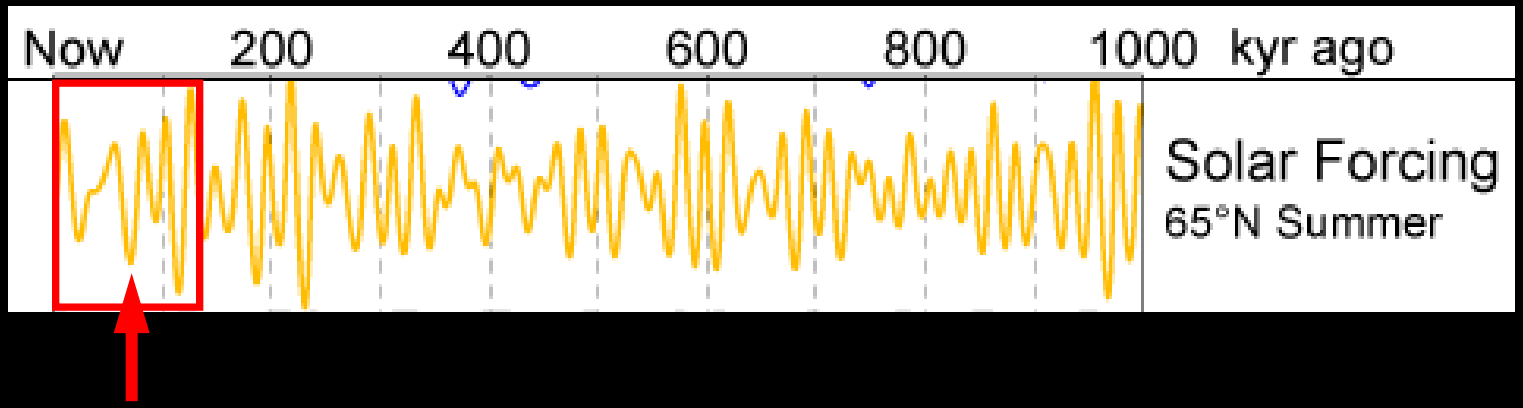
Eccentricity
~ 100, 400 kyr

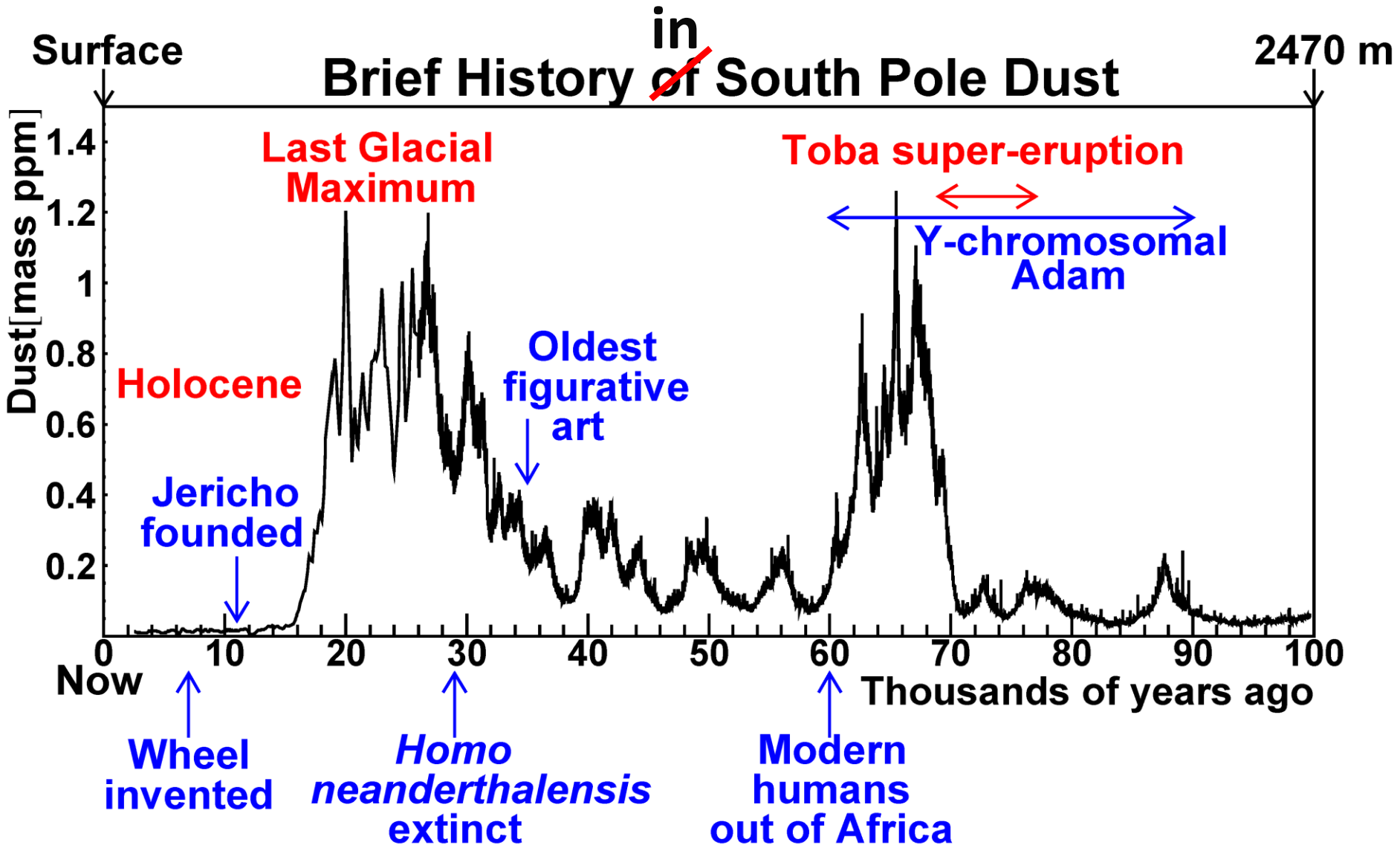


Obliquity
41 kyr

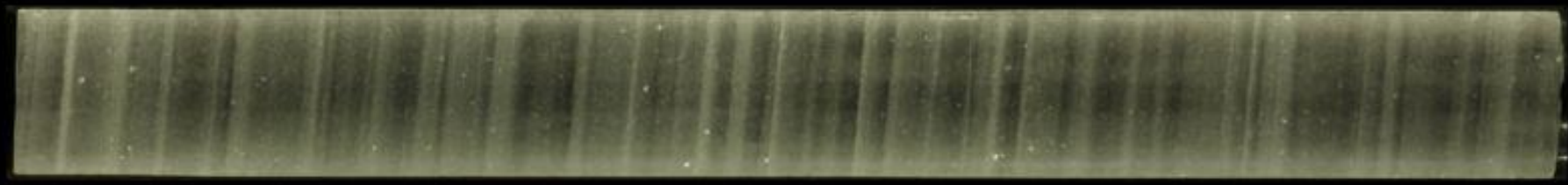


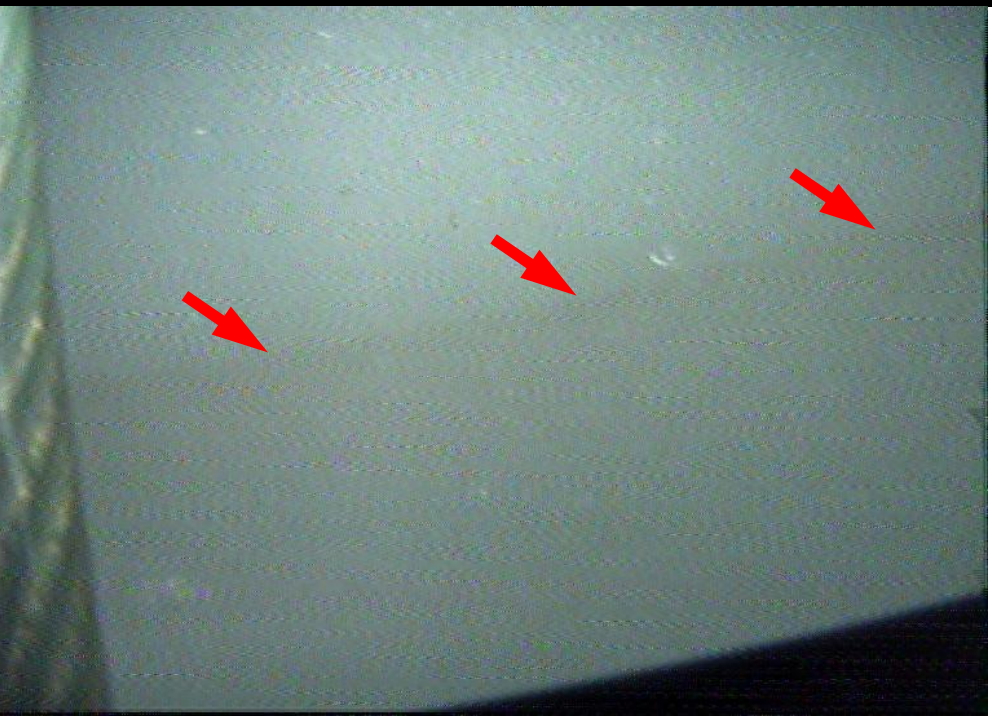
Precession
~20 kyr



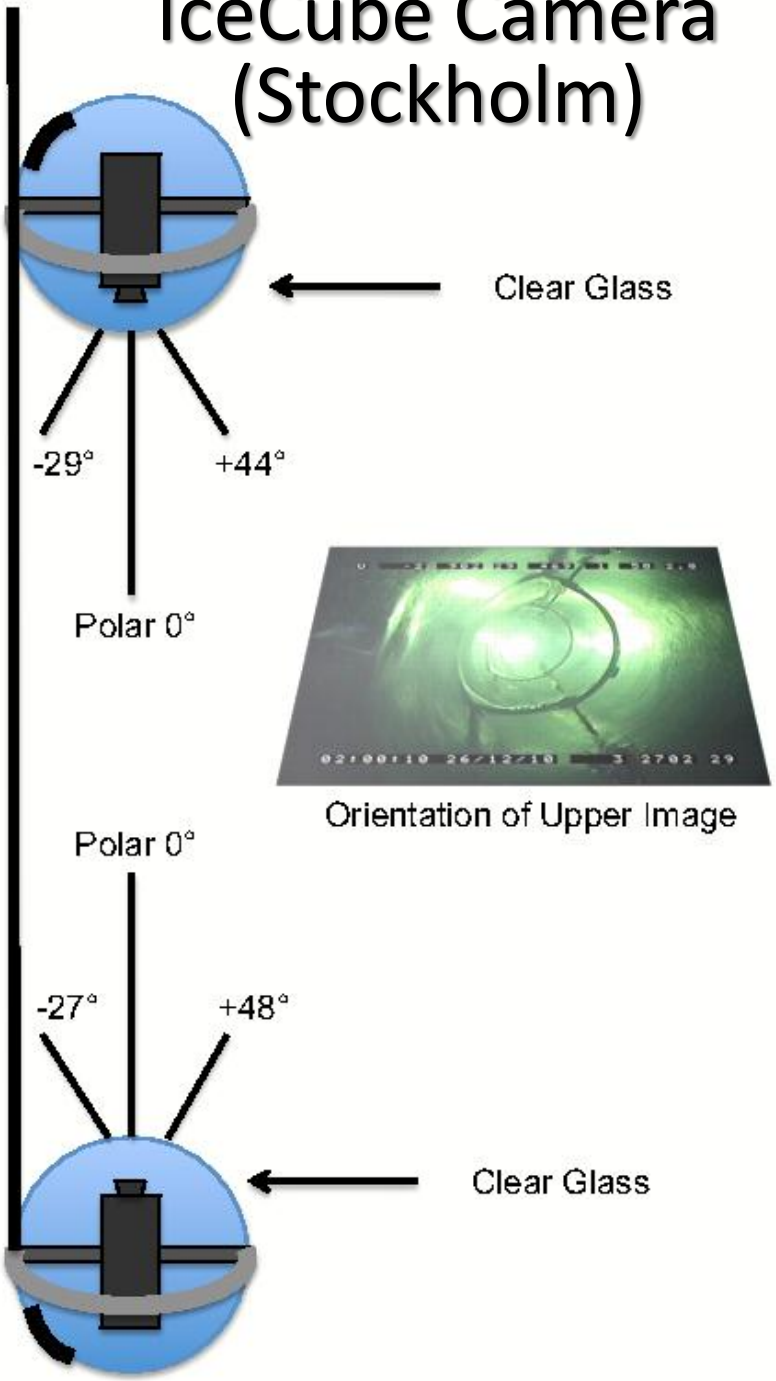

Brief History in South Pole Dust
Surface
2470 m
Dust[mass ppm]
1.4
1.2
1
0.8
0.6
0.4
0.2
Last Glacial Maximum
Toba super-eruption
Y-chromosomal Adam
Holocene
Oldest figurative art
Jericho founded
0
10
20
30
40
50
60
70
80
90
100
Now
Thousands of years ago
Wheel invented
Homo neanderthalensis extinct
Modern humans out of Africa

Ice Cores

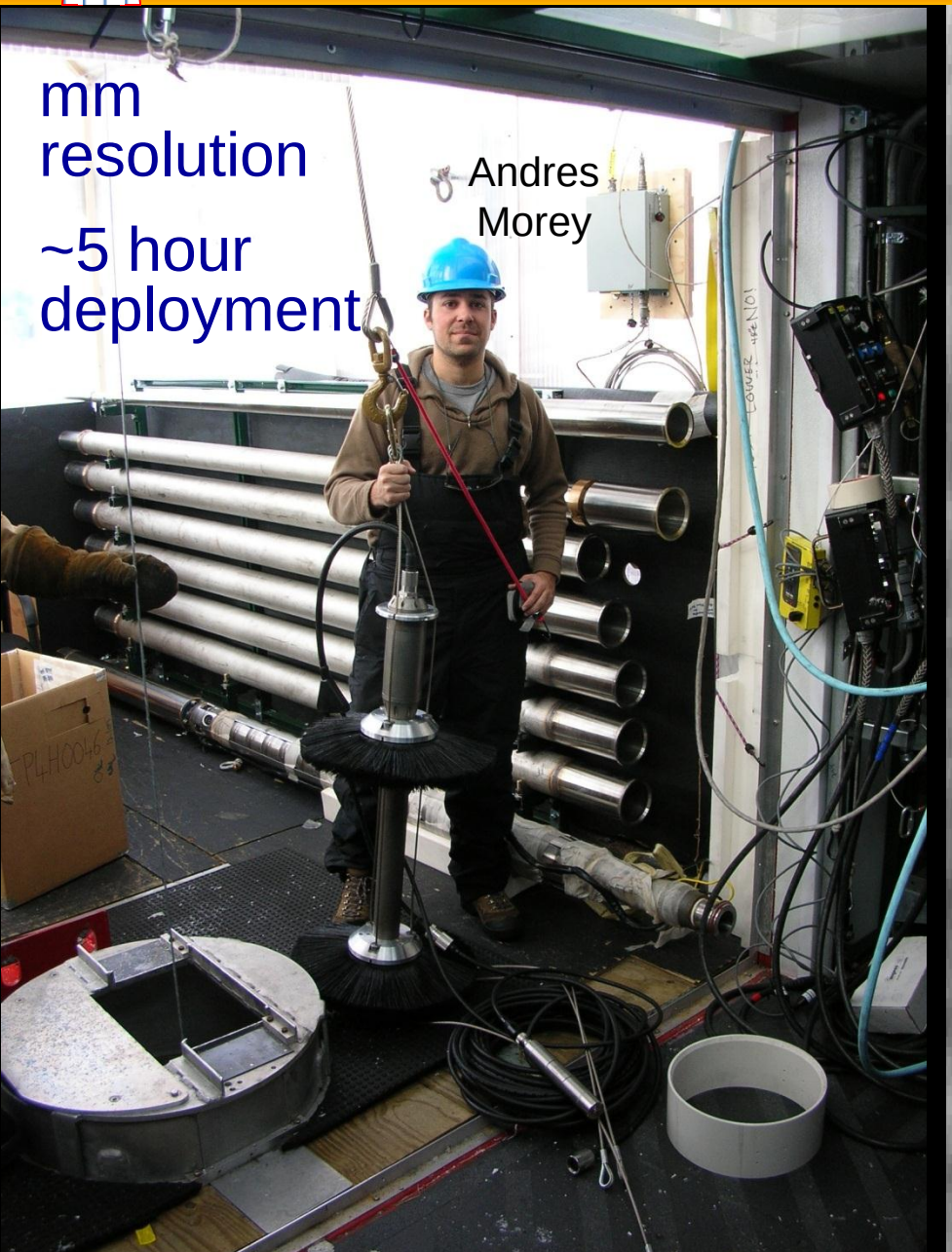


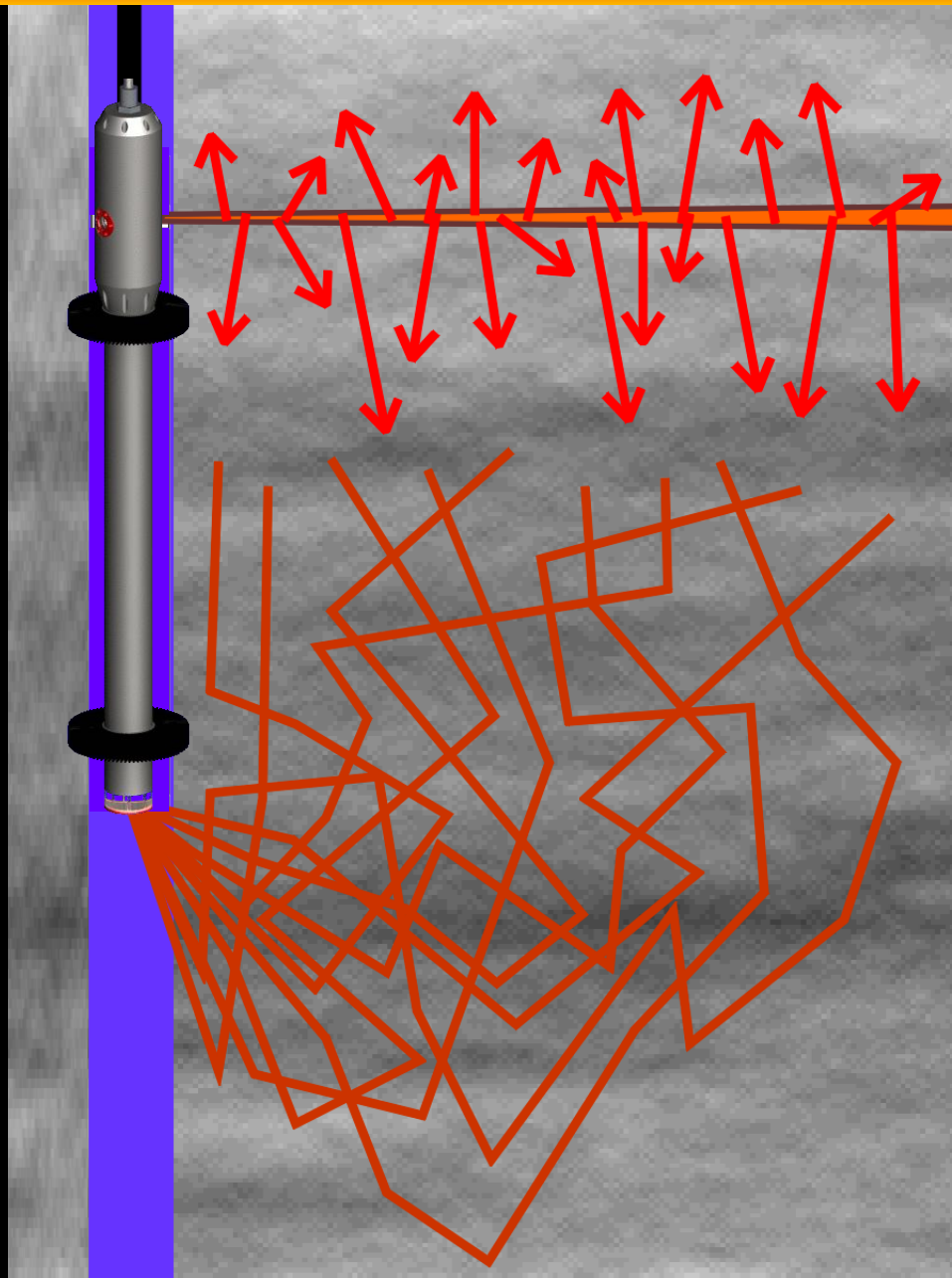


IceCube Camera (Stockholm)

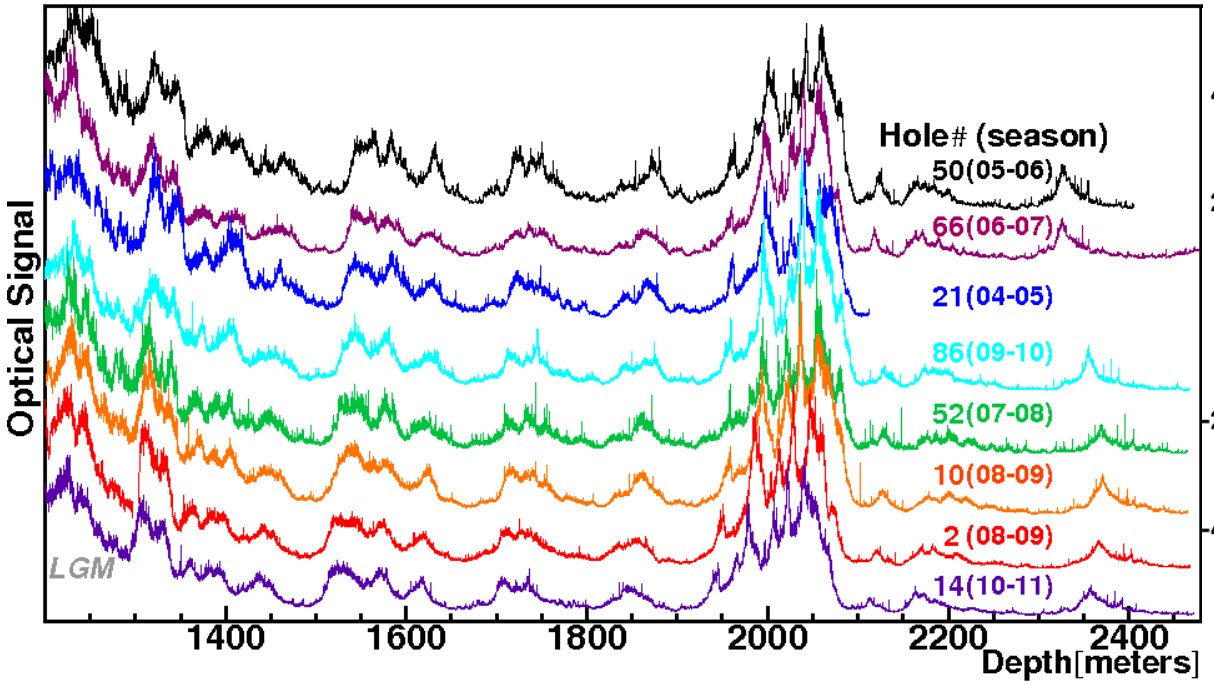


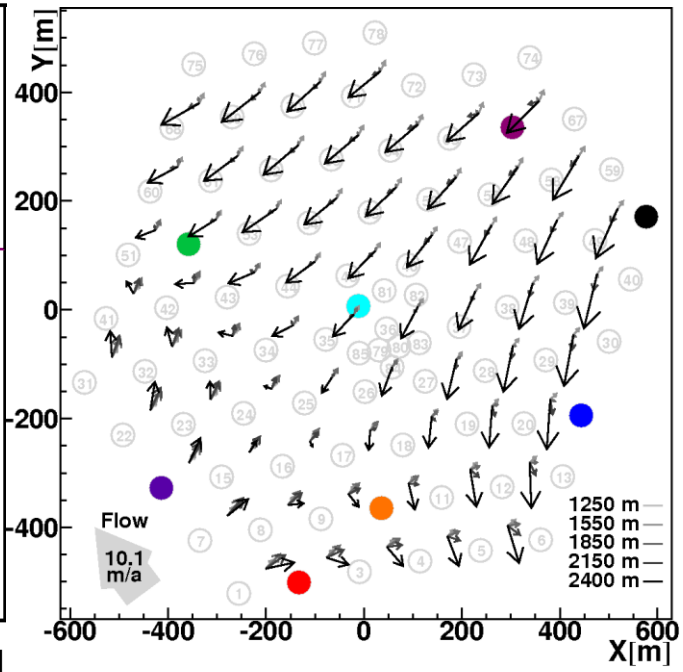
Borehole Laser Dust Logger

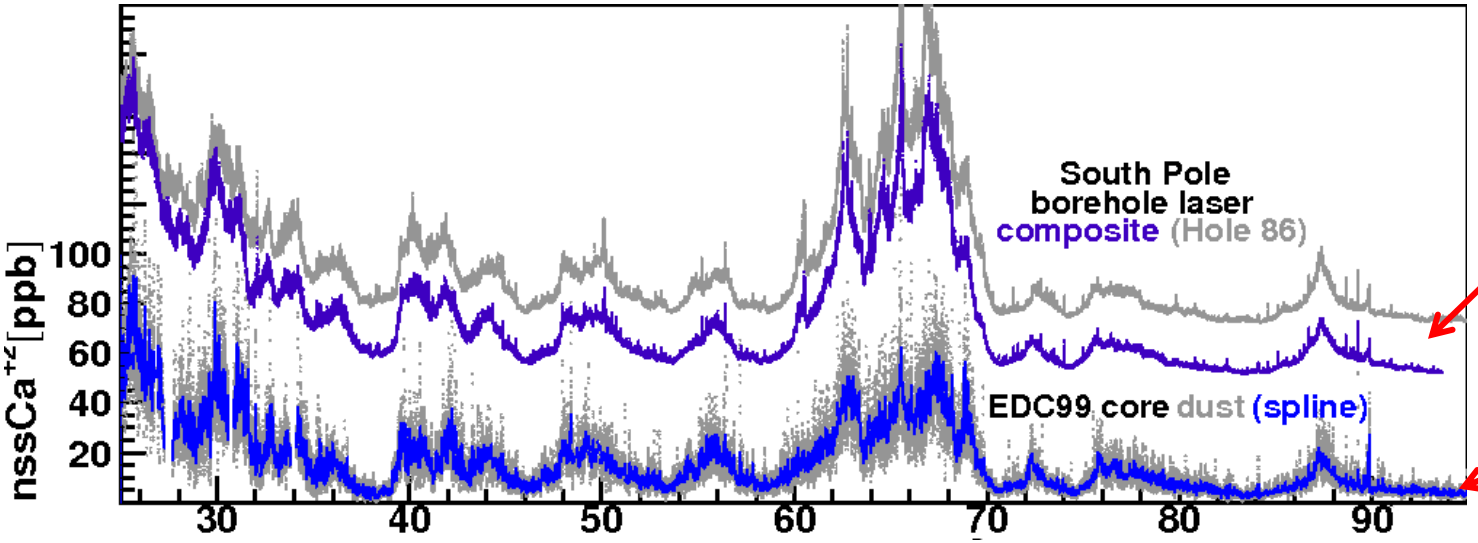




The IceCube Antarctic Dust Record



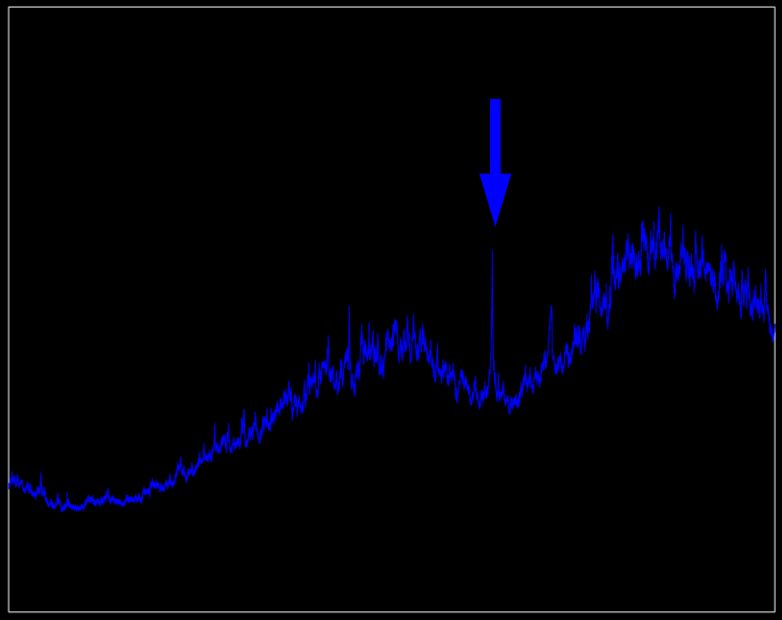


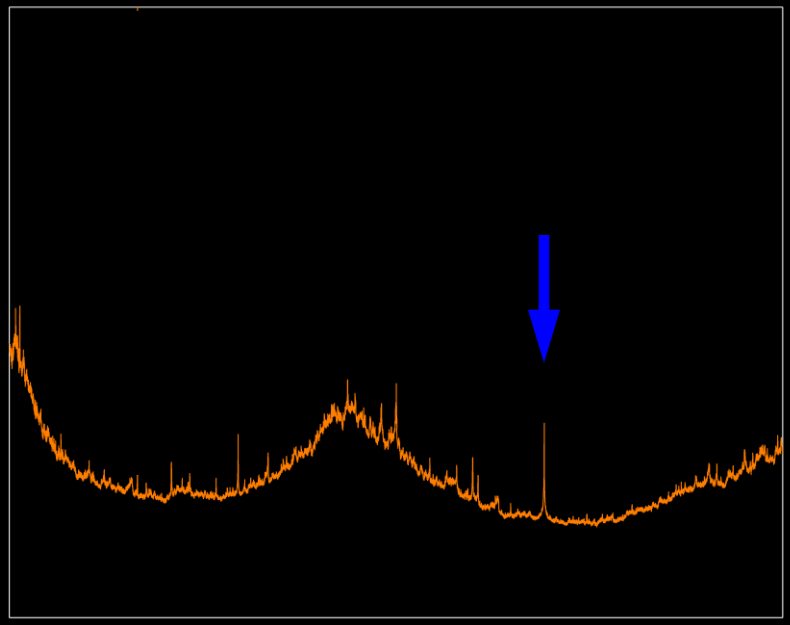


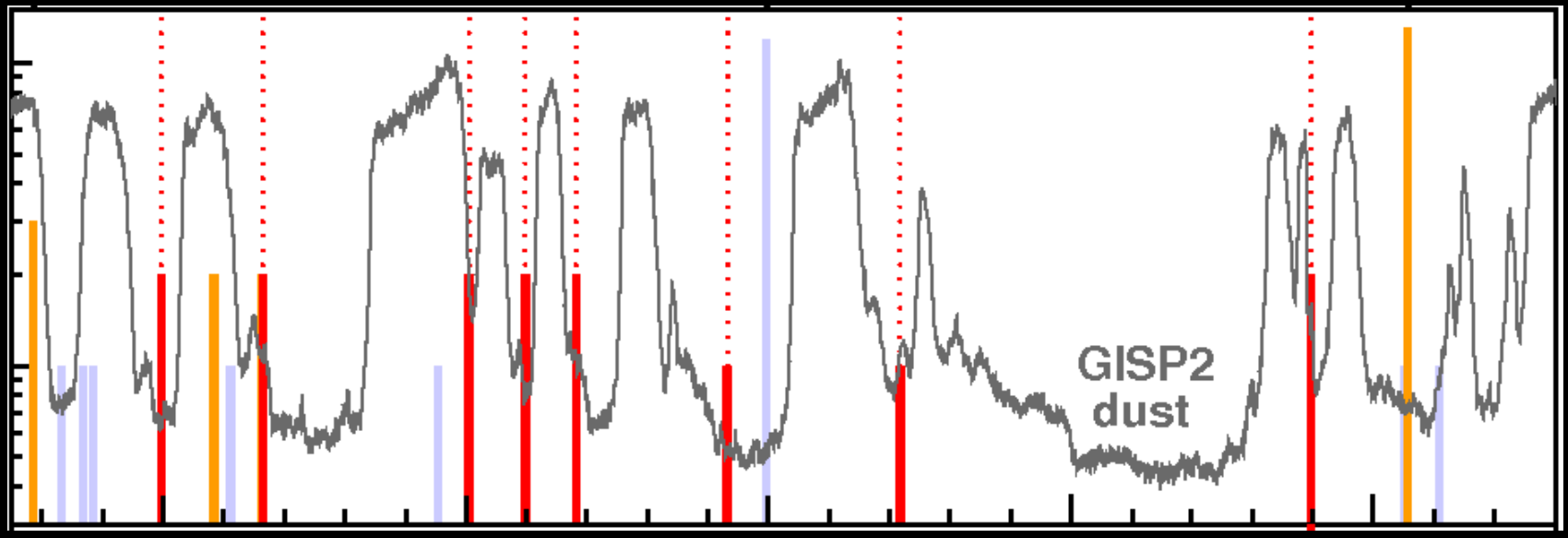
Borehole laser

Dome C Ice core

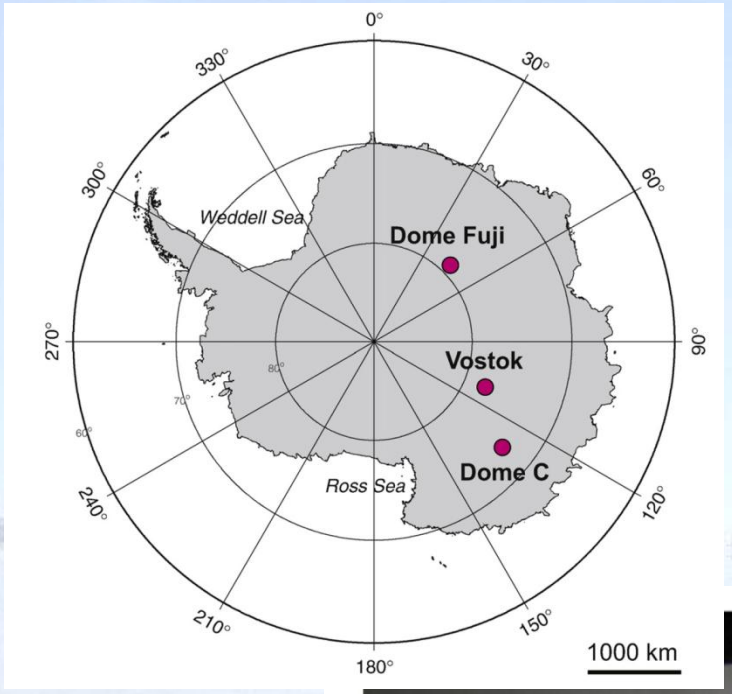
Fallout layers & millennial climate change

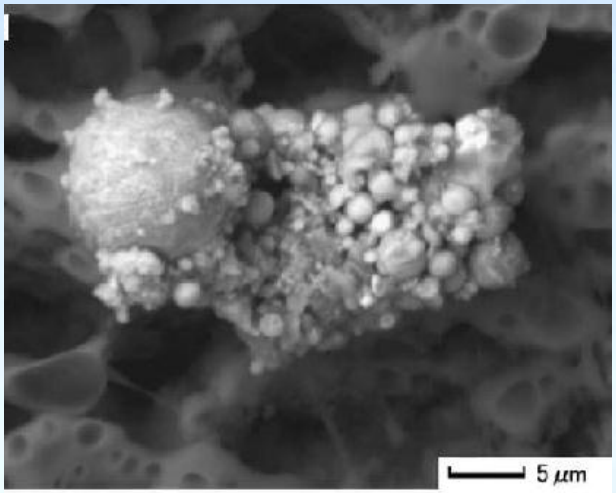


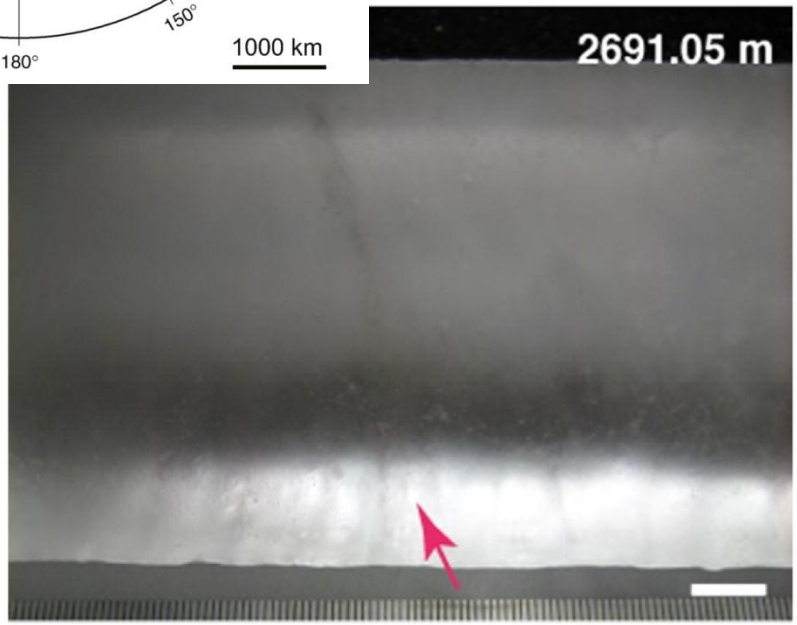


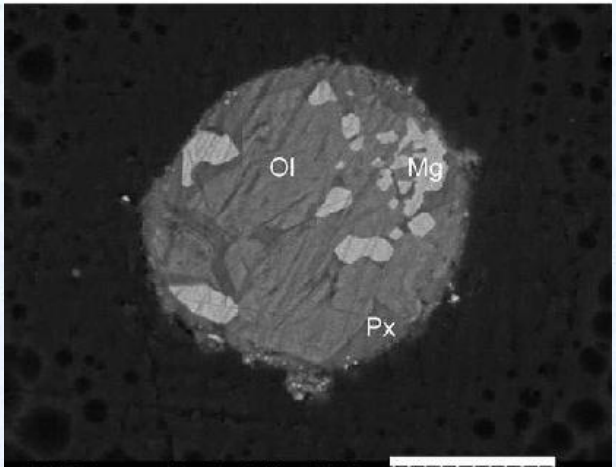


Antarctic extraterrestrial impact layers 434 and 481 ka





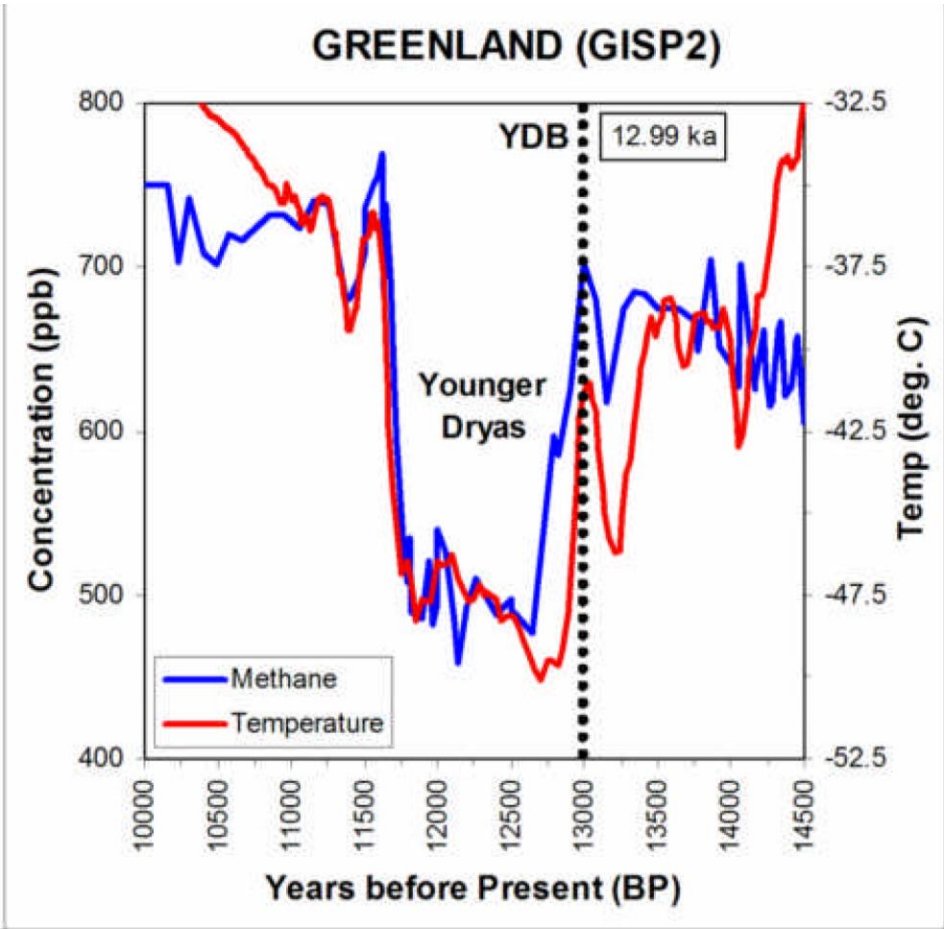


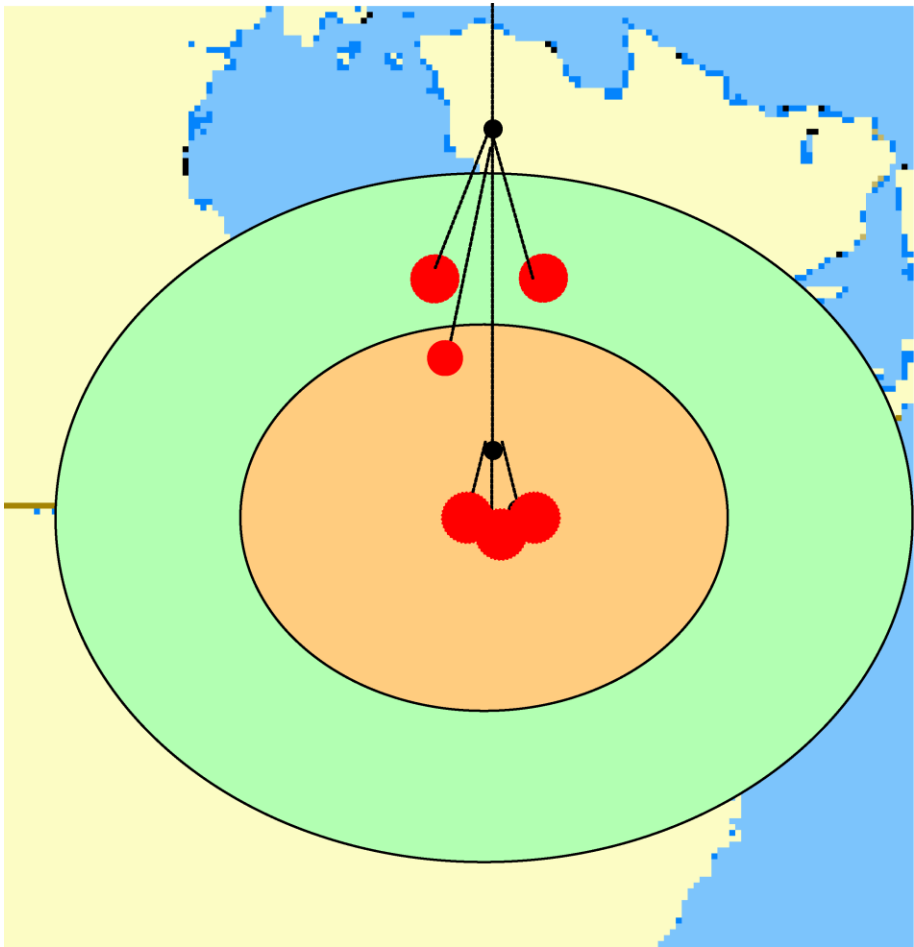


Particulates from Dome Fuji core (K. Misawa *et al*. 2010)

Evidence for an extraterrestrial impact 12,900 years ago that contributed to the megafaunal extinctions and the Younger Dryas cooling

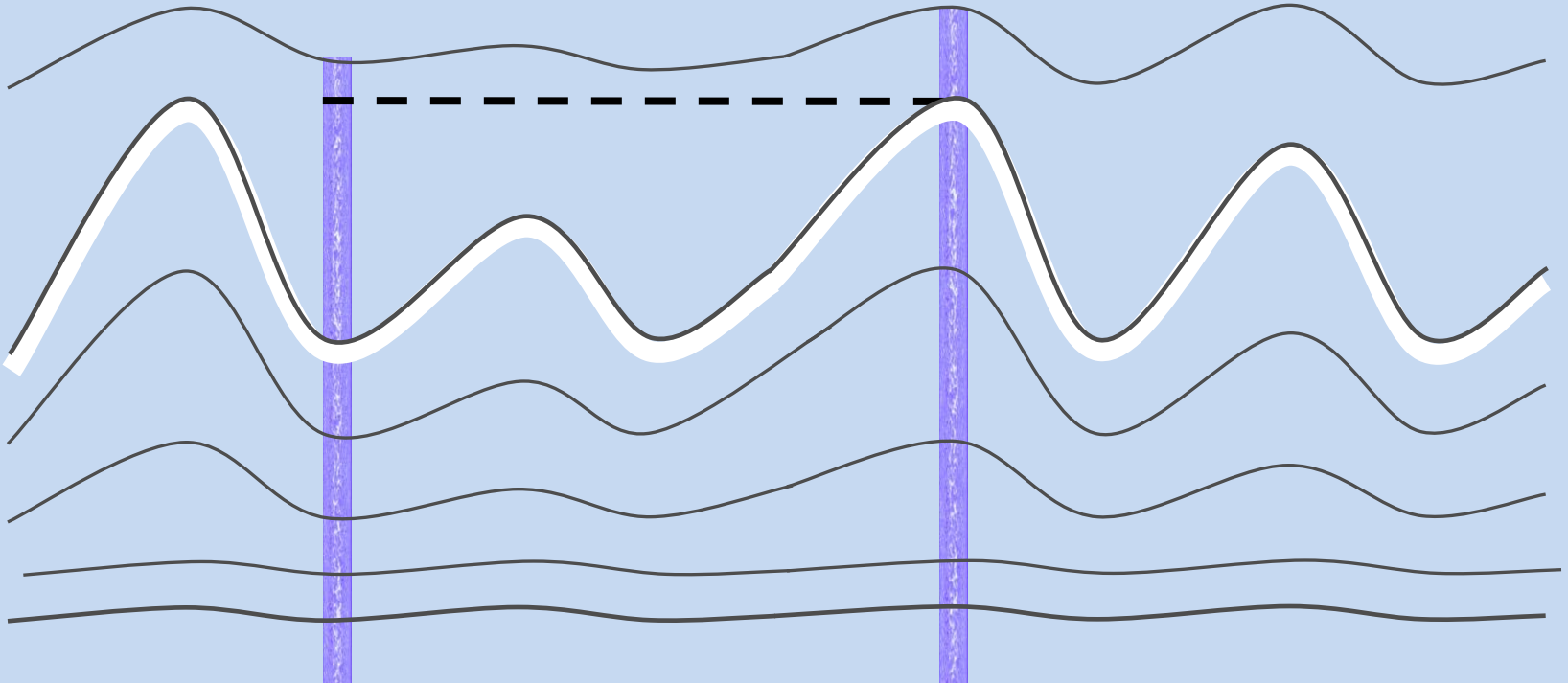
R. B. Firestone[a,b], A. West[c], J. P. Kennett[d], L. Becker[e], T. E. Bunch[f], Z. S. Revay[g], P. H. Schultz[h], T. Belgya[g], D. J. Kennett[i], J. M. Erlandson[i], O. J. Dickenson[j], A. C. Goodyear[k], R. S. Harris[h], G. A. Howard[l], J. B. Kloosterman[m], P. Lechler[n], P. A. Mayewski[o], J. Montgomery[j], R. Poreda[p], T. Darrah[p], S. S. Que Hee[q], A. R. Smith[a], A. Stich[r], W. Topping[s], J. H. Wittke[f], and W. S. Wolbach[r]



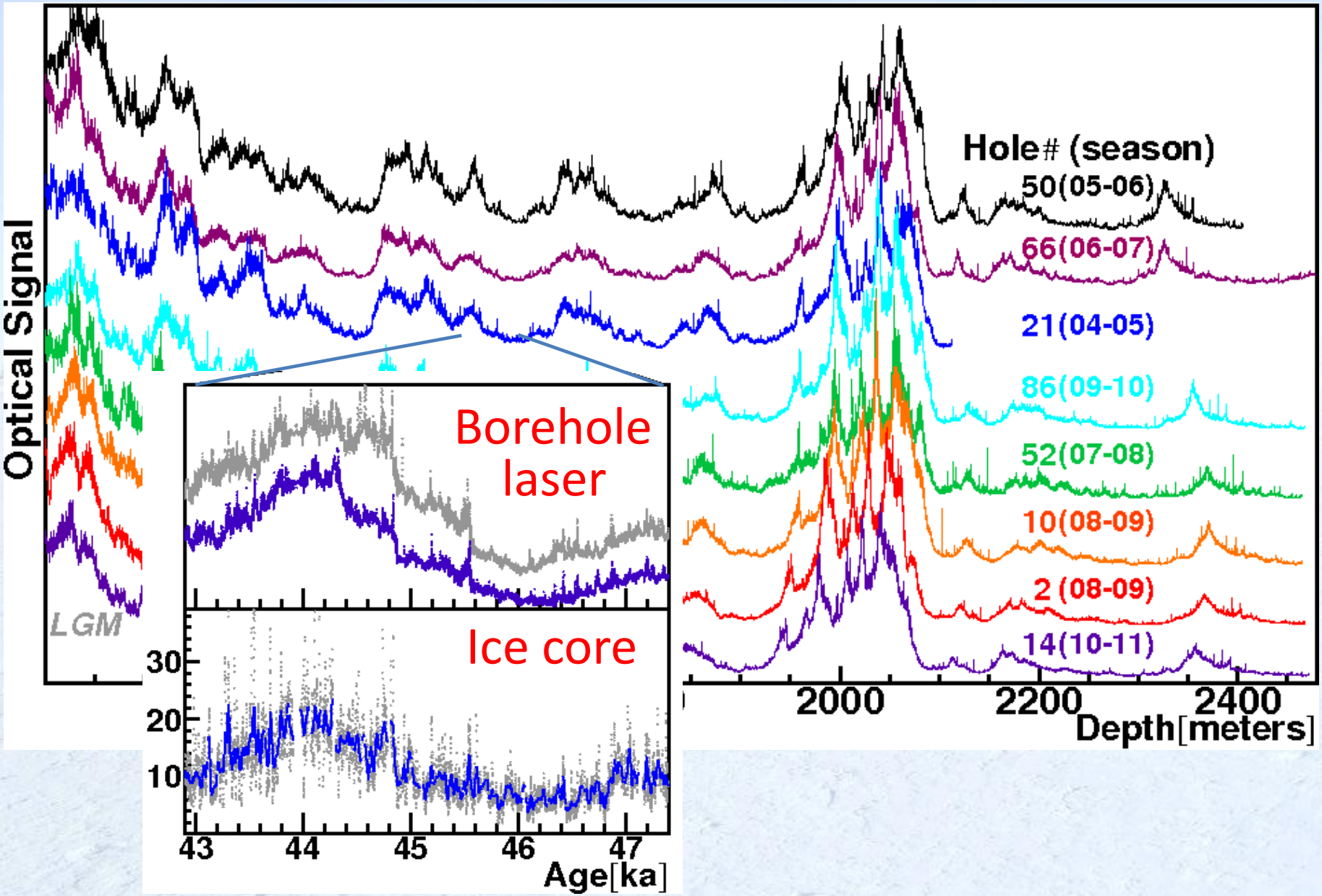


Wind speed from surface paleoroughness

Buried horizons imprint ancient dunes



Dust Map of South Pole Paleosurface

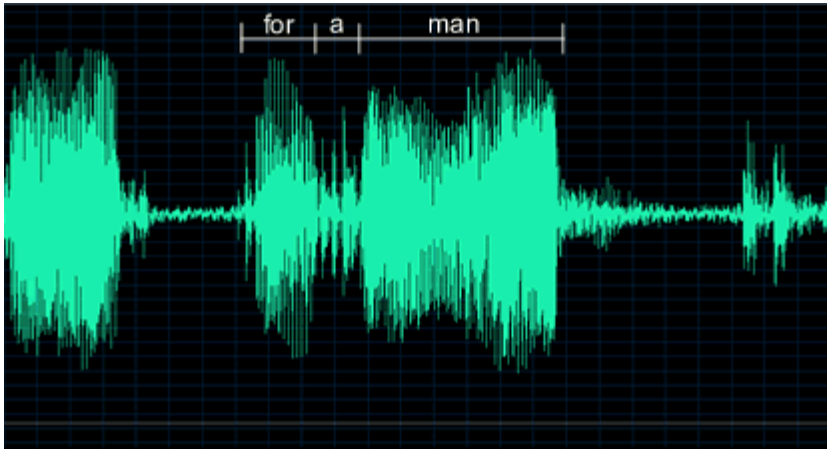


Dynamic Time Warping Synchronization of Ice Core Data

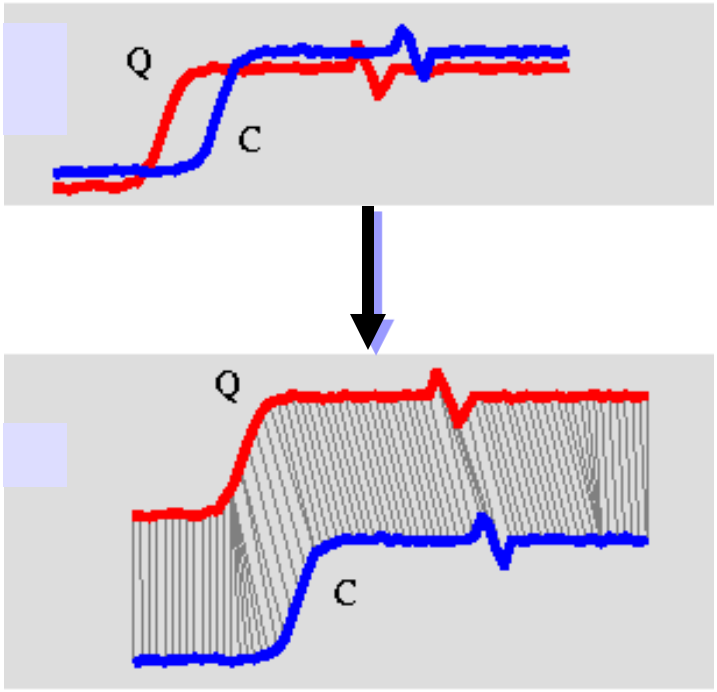
DTW

Biometrics

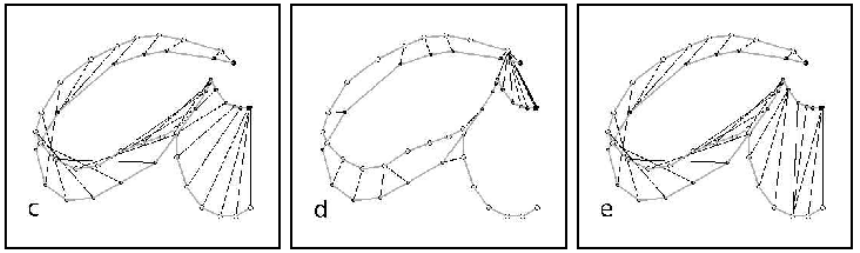
Speech recognition



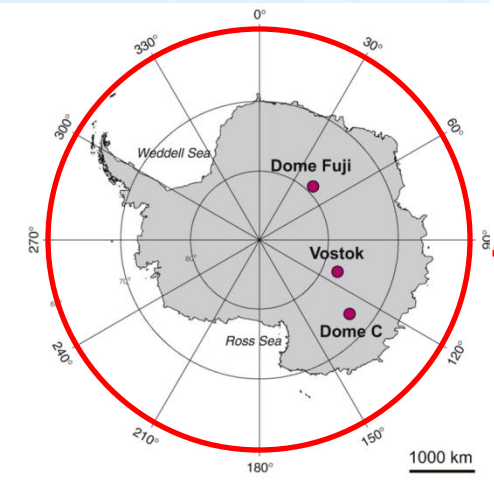
Signal matching

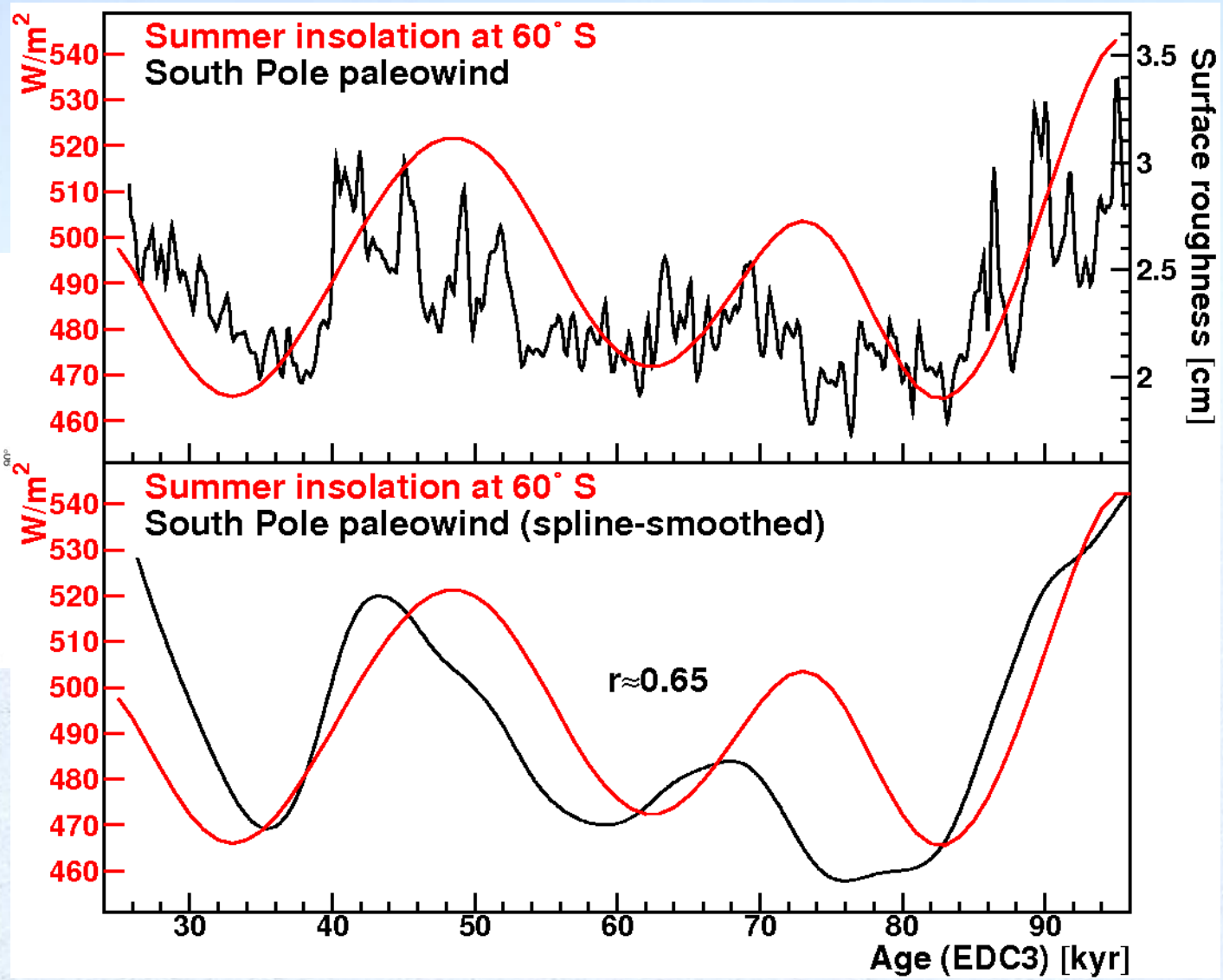


Handwriting



South Pole Paleowind Speed

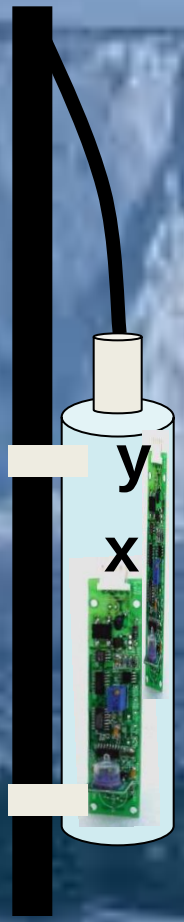




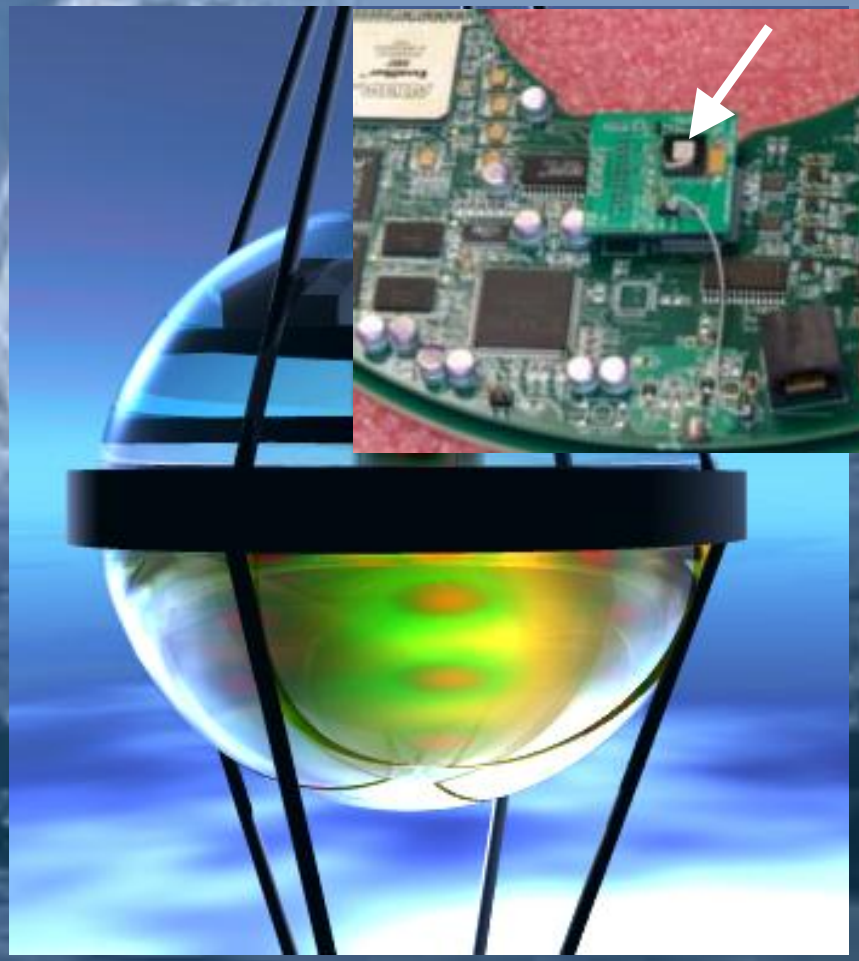
IceCube inclinometers

Electrolytic

Resolution: 0.01°

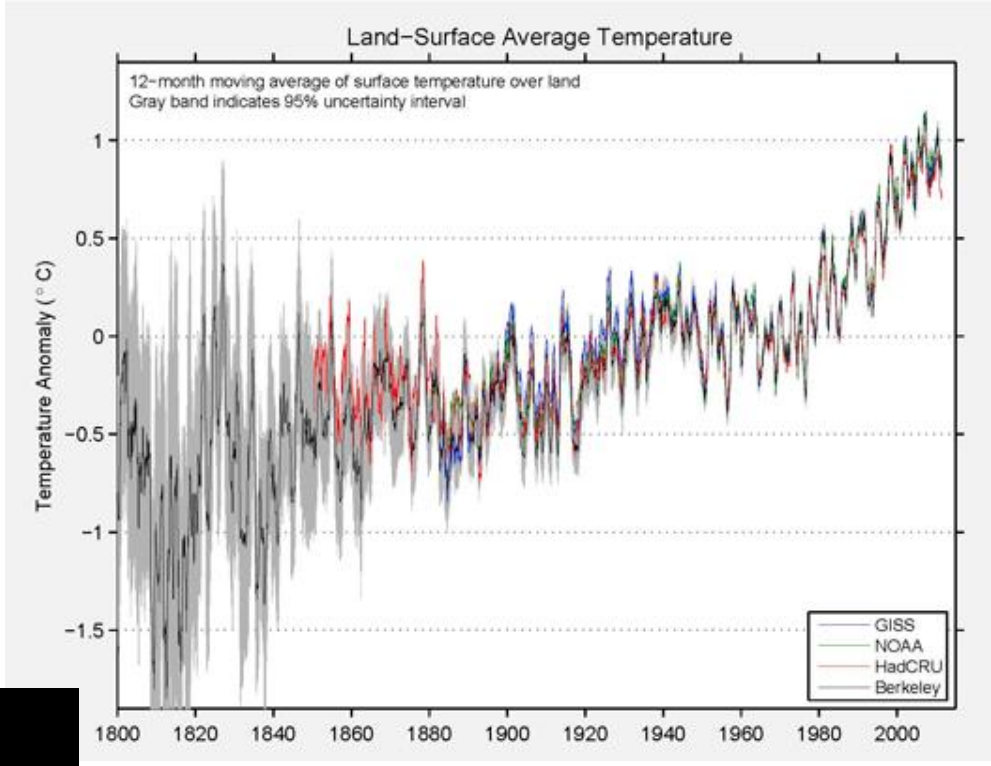


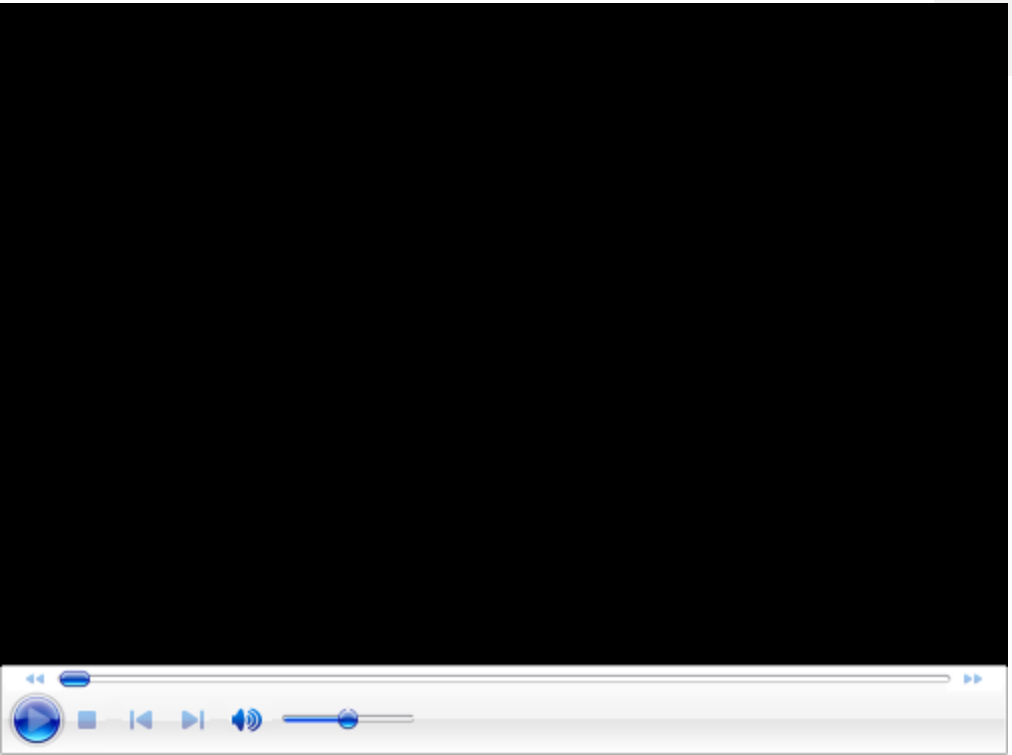
DOM-Embedded micromechanical



Resolution: 0.025°

Berkeley Earth Surface Temperature





R. Muller,

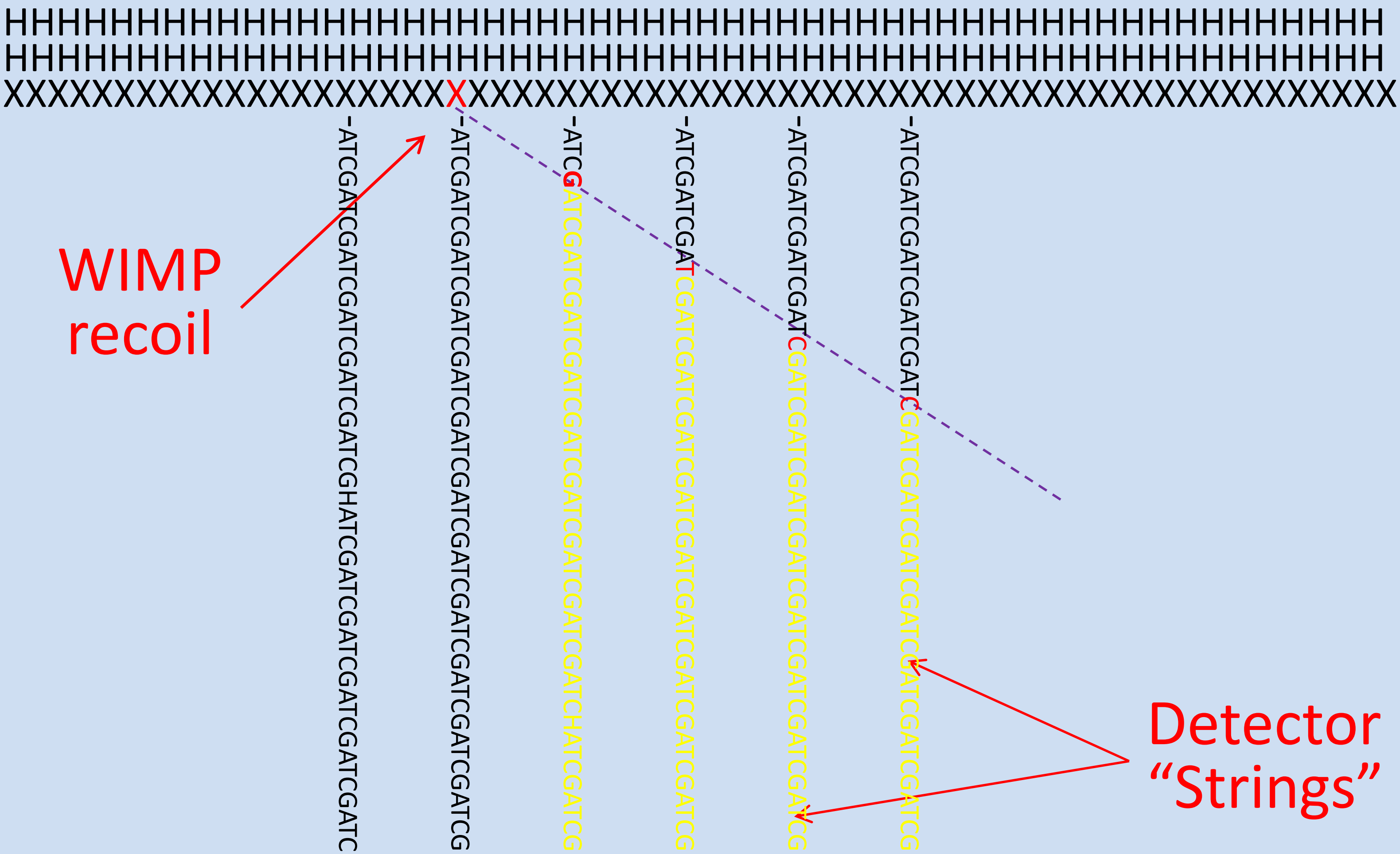
R. Rohde,

S. Perlmutter,

et al.

DNA WIMP Detector

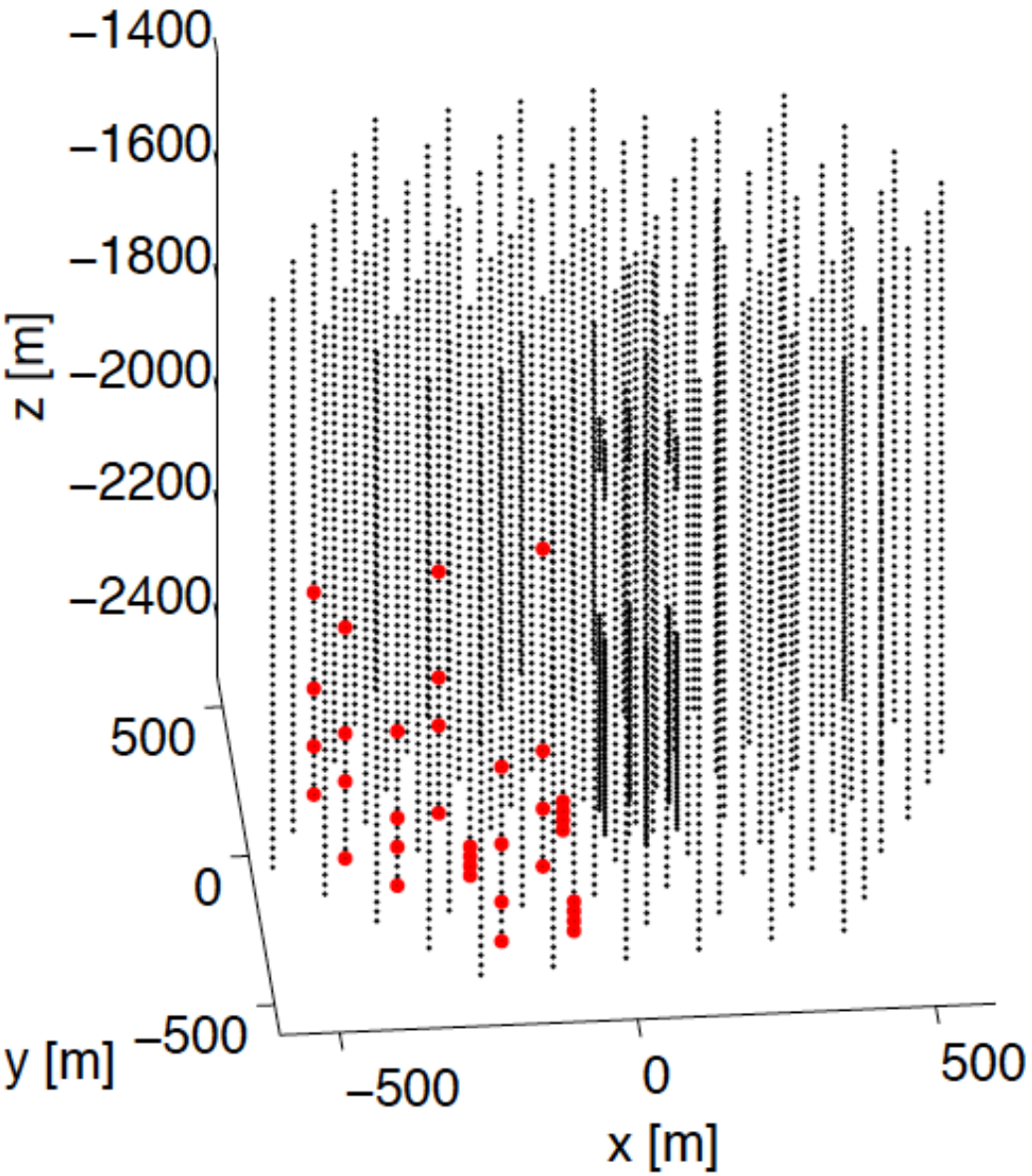
Andzej Drukier

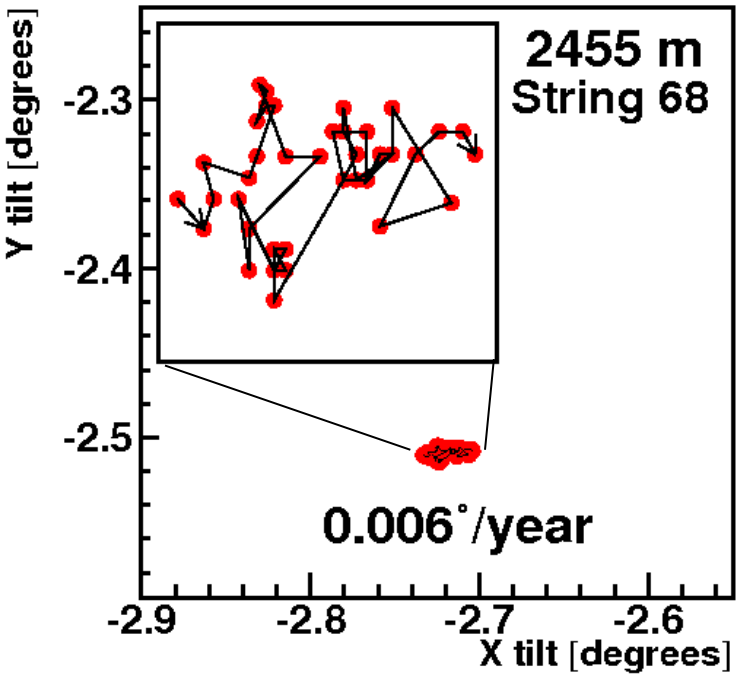


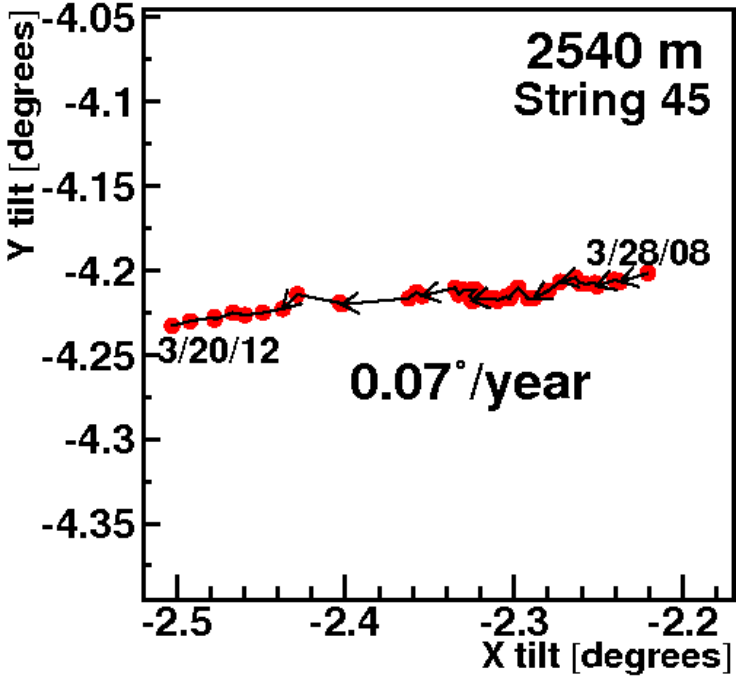
- => **high probability of detection**
- => **high number of ssDNA broken**
- => **characteristic cut-off pattern (ssDNA ladder)**


Thank you

Microinclinometers record abrupt onset of shear of ice with depth



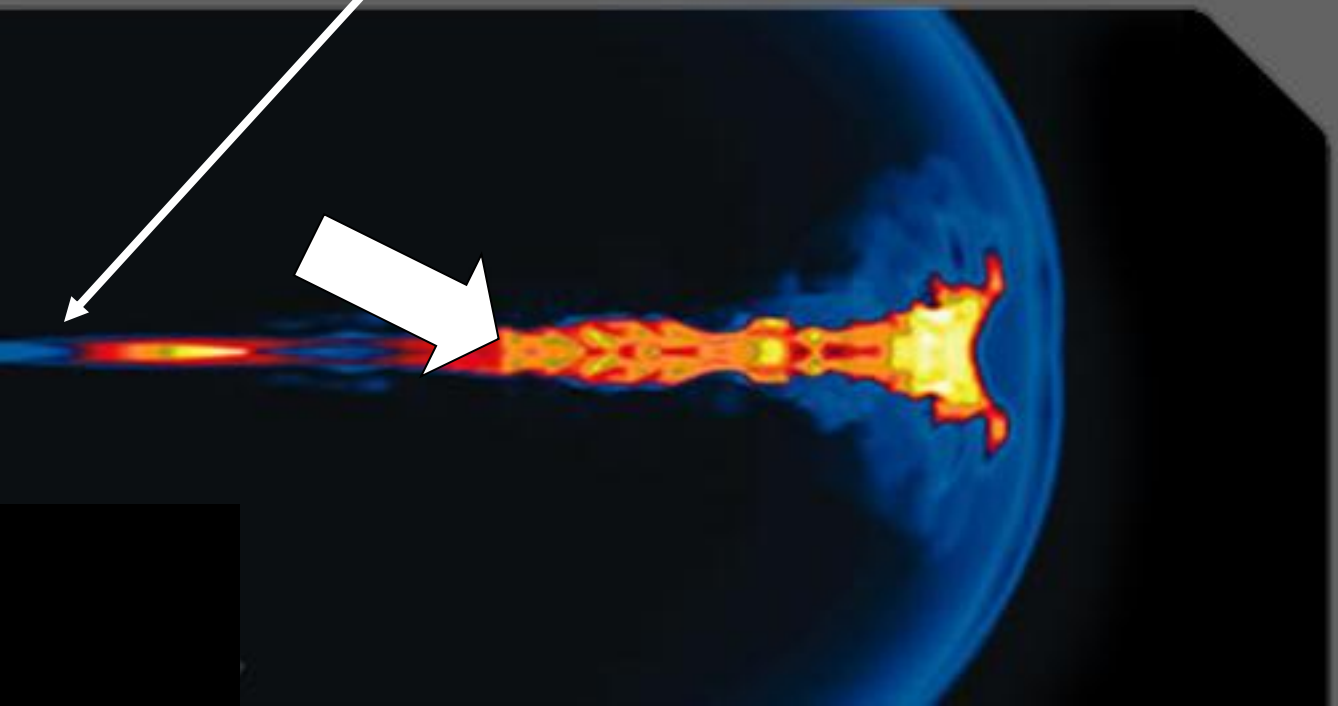




collapse of massive star produces a

gamma ray burst

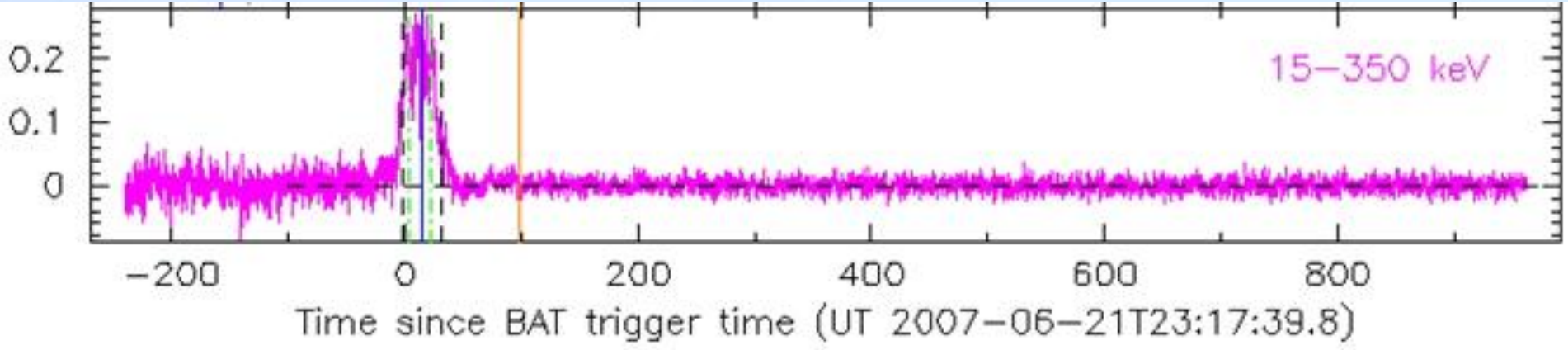
spinning black hole



shocks produced in the outflow of the spinning black hole: electrons (and protons ?)

GRB Analysis method

Use satellite measurements as trigger:



Look for neutrinos in the direction of GRB in a short (seconds to minutes) time window….

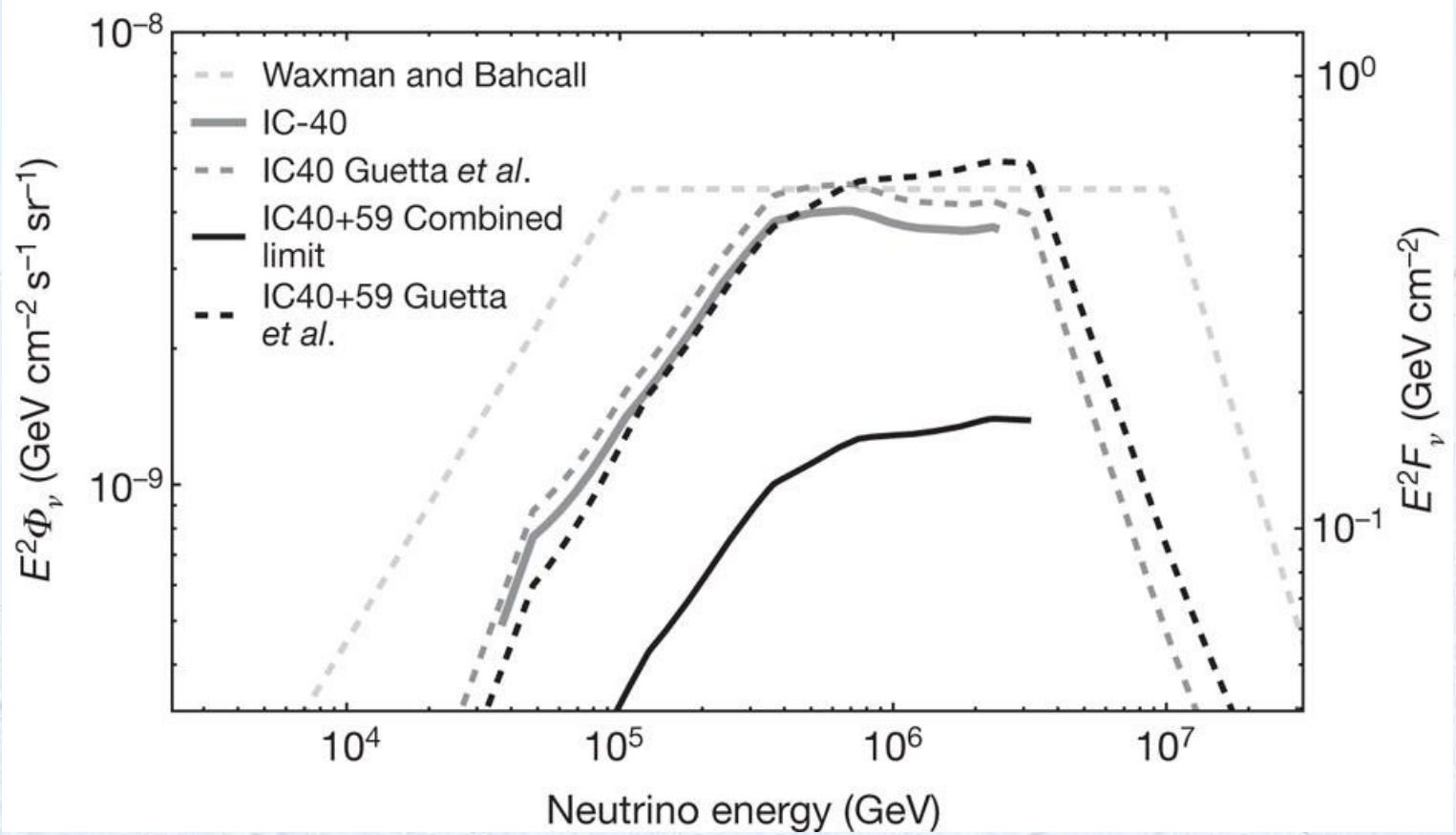
And find…

NOTHING SO FAR :-(

Search for neutrinos from GRBs, results

“An absence of neutrinos associated with cosmic-ray acceleration in γ-ray bursts”

Nature, Volume: 484,Pages:351–354, Date published:(19 April 2012)



“These limits exclude all tested models with their standard parameters and uncertainties on those parameters”

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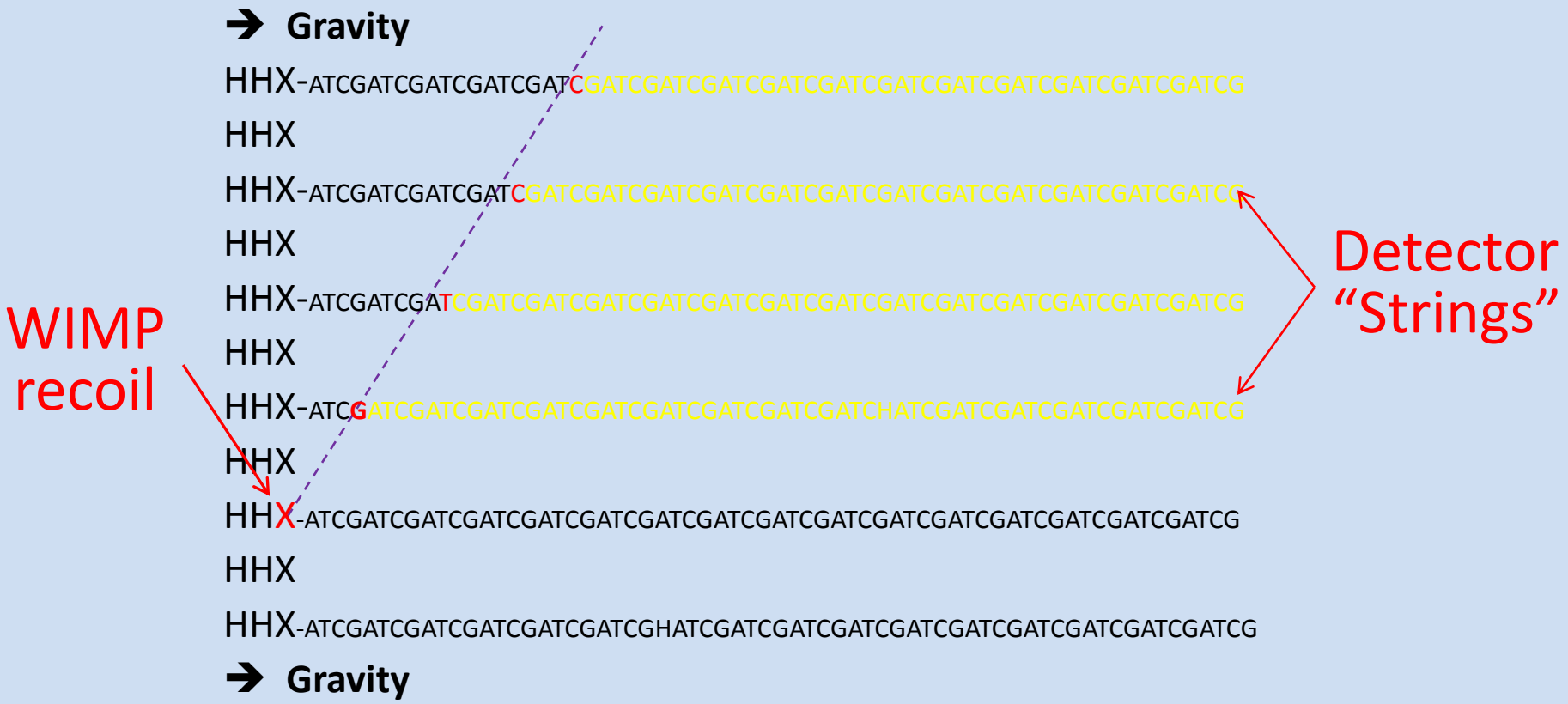

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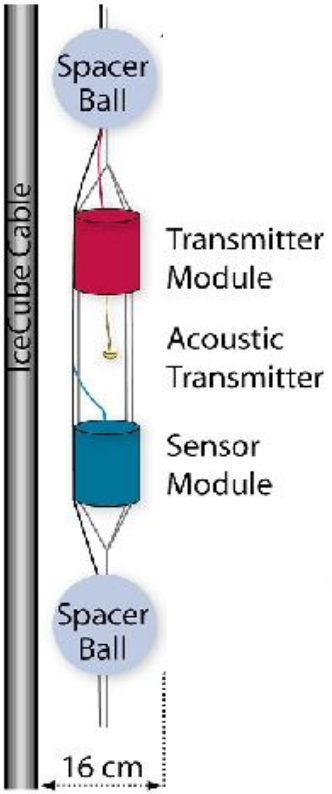
SP Acoustic Test Setup (SPATS)

R. Nahnhauer, J. Vandenbroucke *et al.*



$\lambda_{att} \approx 300$ m @ 20 kHz