TEACHING ANTARCTIC ASTRONOMY

William TOBIN

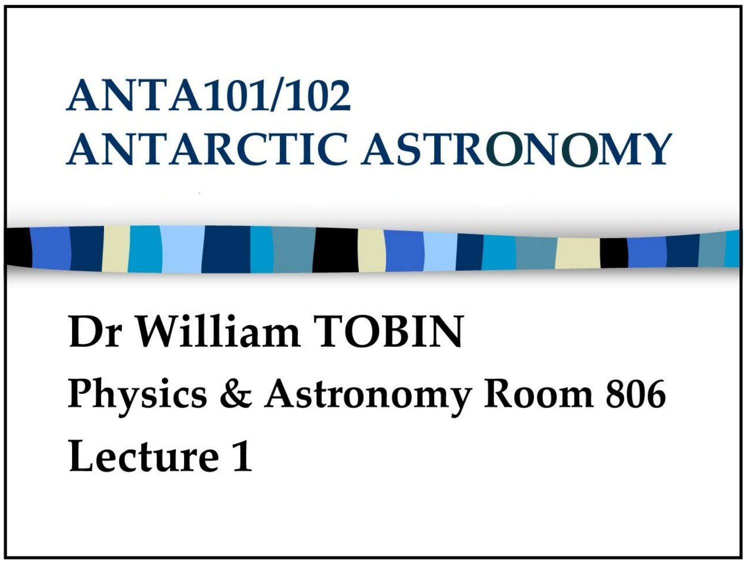
recently retired from

Department of Physics & Astronomy
University of Canterbury
Christchurch, New Zealand
william.tobin@wanadoo.fr

The experience of university-level teaching of 'Antarctic Astronomy' is recounted and lessons are found for the research enterprise

Introduction

Writing grant applications is like university teaching: a thorough understanding of fundamentals is essential. To be effective, it's often crucial to use simple language and to remind students—and harassed assessment panels—of factors that the teacher/researcher may omit as obvious through over-familiarity. So in the hope of assisting the reader to pen even better grant applications, here in simple terms are what I consider the obvious fundamentals about *Antarctic Astronomy,* distilled from teaching the topic to undergraduates, and accompanied by a selection of my lectures' PowerPoint slides.



Antarctic Studies Course Outline (2005).

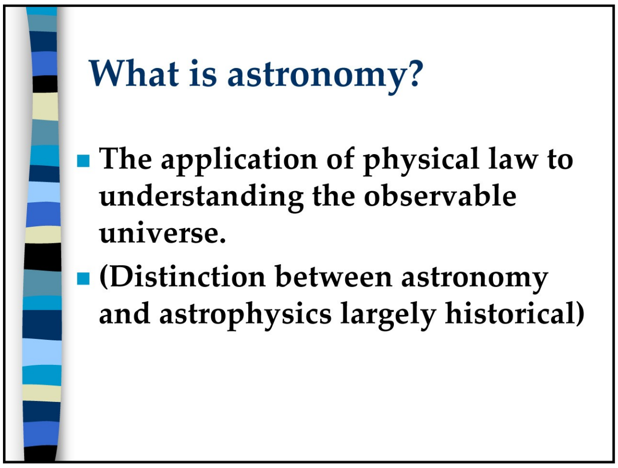
Lecture Number	Date	Lecturer	Topic
	2005	**ANTA 101:Antarctic Studies=Blocks 1-4**	**Room C1, 8am**
		ANTA 102:Antarctic Studies=Blocks 1-2	ALL LECTURES IN C1
		ANTA 103:Antarctic Studies=Blocks 3-4	
	Semester 1		
Block 1	**February**		
1	Tuesday 22	Michelle Finnemore, Gateway Antarctica	Welcome and Introduction to the Course
2	Friday 25	Michelle Finnemore, Gateway Antarctica	Legal Issues: Sovereignty in Antarctica
	March		
3	Tuesday 1	Michelle Finnemore, Gateway Antarctica	Legal Issues2: The Antarctic Treaty System
4	Friday 4	Bryan Storey, Gateway Antarctica	Tectonic Setting of Antarctica
5	Tuesday 8	Bryan Storey, Gateway Antarctica	Rocks
6	Friday 11	Bryan Storey, Gateway Antarctica	Time
7	Tuesday 15	Bryan Storey, Gateway Antarctica	Antarctica within Gondwana
8	Friday 18	Bryan Storey, Gateway Antarctica	Break-up of Gondwana and the Isolation of Antarctica
9	Tuesday 22	Bryan Storey, Gateway Antarctica	Minerals in Antarctica
10	Friday 25	**NO LECTURES-UNI CLOSED**	
	Semester 1 Break		
Block 2			
	April		
11	Tuesday 19	Ian Owens, Geography	Weather and climate: extremes of temperature
12	Friday 22	Ian Owens, Geography	Weather and climate: windiness
13	Tuesday 26	Ian Owens, Geography	Weather and climate: (a) comfort and (b) precipitation
14	Friday 29	**TEST ONE**	
	May		
15	Tuesday 3	Lou Sanson, Antarctica NZ	Representing NZ's Interests in Antarctica
16	Friday 6	Wendy Lawson, Geography	Glaciology
17	Tuesday 10	Wendy Lawson, Geography	Glaciology
18	Friday 13	Colin Goodrich, Sociology	Antarctic Tourism
19	Tuesday 17	Ellen Hampson, Christchurch Polytech	Antarctic Tourism Trends
20	Friday 20	Baden Norris, Lyttelton Museum	Antarctic Exploration: The Race for Discovery
21	Tuesday 24	Baden Norris, Lyttelton Museum	Antarctic Exploration: The Race for Discovery
22	Friday 27	William Tobin, Physics	Antarctic Astronomy
23	Tuesday 31	William Tobin, Physics	Antarctic Astronomy
	June		
24	Friday 3	Adrian McDonald, Physics	Atmospheric Physics
25	Tuesday 7	Adrian McDonald, Physics	Atmospheric Physics
26	Friday 10	**Test Two**	
	Semester 1 Ends		
	Semester 2	**ANTA 103:Antarctic Studies=Blocks 3-4**	
Block 3			
	July		
27	Tuesday 12	Michelle Finnemore, Gateway Antarctica	
28	Friday 15	Paul Broady, PAMS	Plants on Land/Responses to a Changing Environment
29	Tuesday 19	Paul Broady, PAMS	Plants on Land/Life in Cold Deserts
30	Friday 22	Paul Broady, PAMS	Plants on Land/Furthest South and Hottest Antarctica
31	Tuesday 26	Paul Broady, PAMS	Plants in Water/Extreme Lakes and Ponds
32	Friday 29	Paul Broady, PAMS	Plants in Water/Go with the Flow, Surviving in Streams
	August		
33	Tuesday 2	David Given, Lincoln University	Ecosystems/SubAntarctic Islands
34	Friday 5	David Given, Lincoln University	Ecosystems/SubAntarctic Islands
35	Tuesday 9	Peter Harper, Gateway Antarctica	Birds/Introduction
36	Friday 12	Peter Harper, Gateway Antarctica	Birds/Distribution and Ecology
37	Tuesday 16	Peter Harper, Gateway Antarctica	Conservation of Antarctic birds
38	Friday 19	**Test Three**	
	Semester 2 Break		
Block 4			
	September		
39	Tuesday 6	Bill Davison, Zoology	Antarctic Animals: Life on Land
40	Friday 9	Bill Davison, Zoology	Antarctic Animals: Life in the Sea
41	Tuesday 13	Bill Davison, Zoology	Southern Ocean Fisheries
42	Friday 16	Malcolm Forster, Zoology	Antarctic Animals: Life in Cold Conditions
43	Tuesday 20	Malcolm Forster, Zoology	Antarctic Animals: To Freeze or not to Freeze
44	Friday 23	Malcolm Forster, Zoology	Antarctic Animals: Living through Winter Darkness
45	Tuesday 27	Gary Steel, Lincoln University	Psychology: Coping with Antarctica
46	Friday 30	Gary Steel, Lincoln University	Psychology: Coping with Antarctica
	October		
47	Tuesday 4	Gary Steel, Lincoln University	Psychology: Coping with Antarctica
48	Friday 7	Neil Gilbert, Antarctica New Zealand	Environmental Challenges facing Antarctica
49	Tuesday 11	Bryan Storey, Gateway Antarctica	Gateway Antarctica & Antarctic Research
50	Friday 14	**Test Four**	
	Semester 2 Ends		

The course

From 2002-2005, I gave two lectures on *Antarctic Astronomy* within a 50-lecture sequence entitled *Antarctic Studies* aimed at first-year undergraduates in all faculties at the University of Canterbury in Christchurch, New Zealand. Coordinated by *Gateway Antarctica* (the University's Antarctic research centre), the course also discusses legal issues, geology and glaciology, weather and climate, atmospheric physics, plant and animal life, exploration, psychology and environmental changes. Since Christchurch is the staging post for US and New Zealand Antarctic operations, the course proves widely popular (despite its 8-9 am time-slot), with some 150 students enroled each year.

What is *Antarctic Astronomy* (1)?

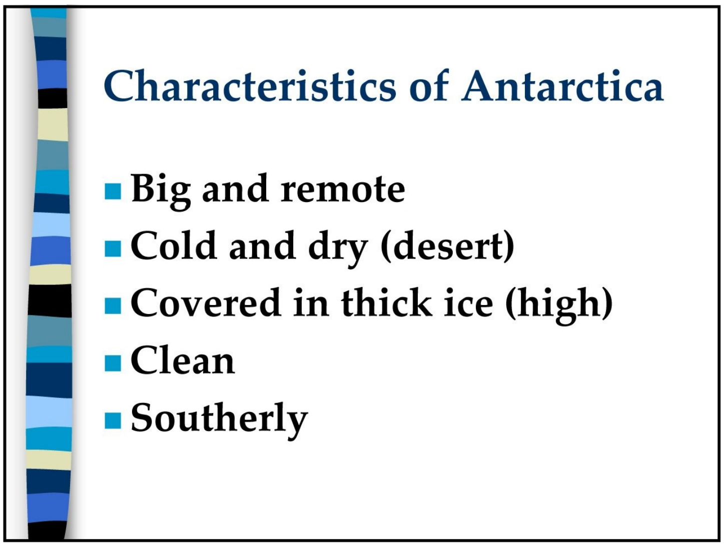
As any astronomer who has attended a cocktail party knows, many people have only the vaguest idea about what astronomers do. So students need telling it has nothing to do with constellations or horoscopes -->



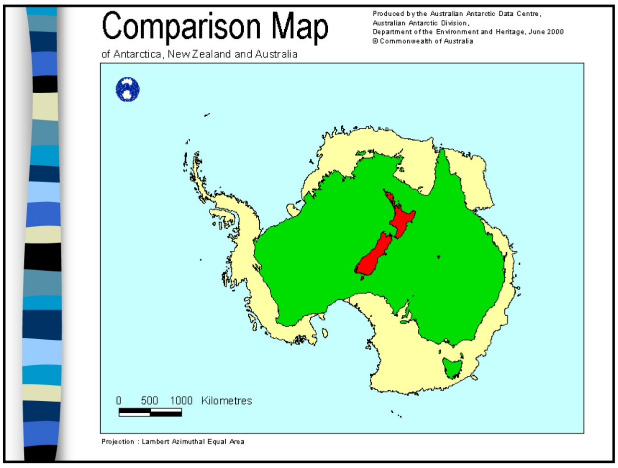
But what about *Antarctic* astronomy? Unlike atmospheric physics, there are no astronominal phenomena specific to the Antarctic (apart from chance events like the total solar eclipse in 2003).

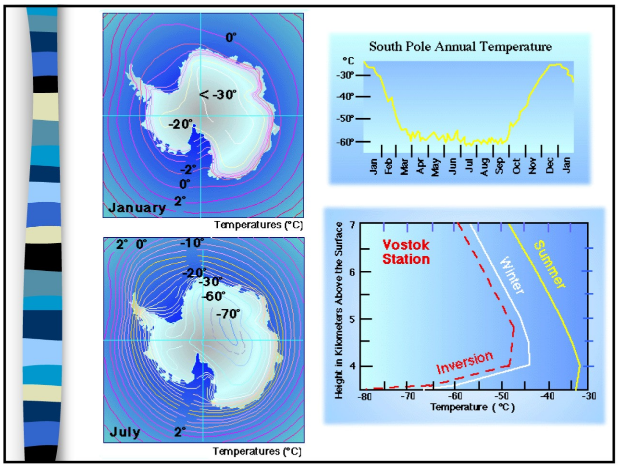
Before *Antarctic Astronomy* can be defined, it's necessary to introduce the several of Antarctica's unique characteristics.

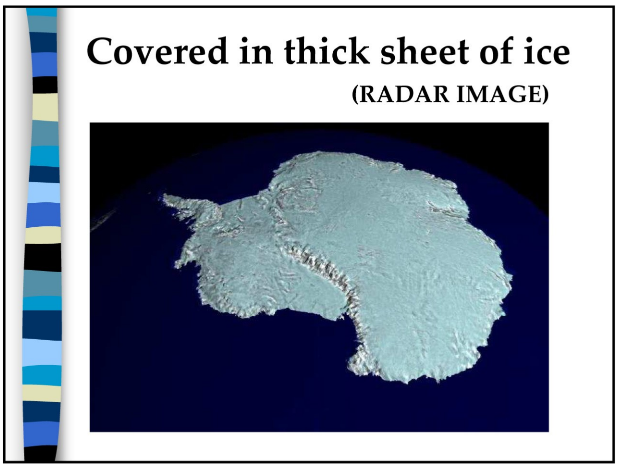
Characteristics of Antarctica relevant to astronomy

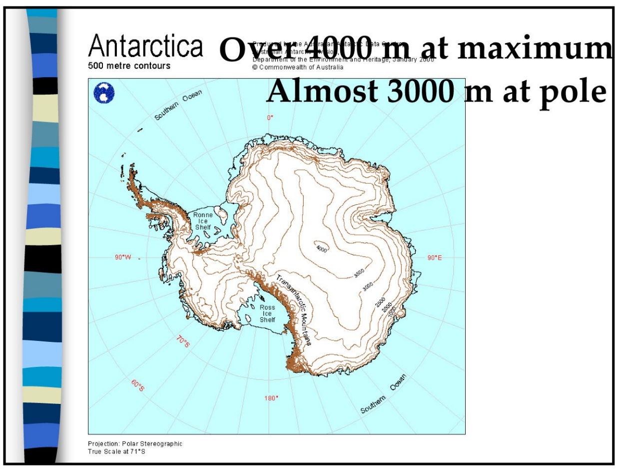


I then expand upon these characteristics :







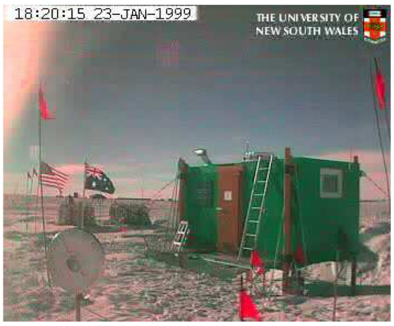


The consequences of Antarctica's southerliness need elaboration:

Characteristics of Antarctica

- <u>Southerly</u>
  - Continuous daylight in summer, night in winter
  - Magnetic field nearly vertical
  - Circumpolar winds

Sun remains above horizon continuously in summer



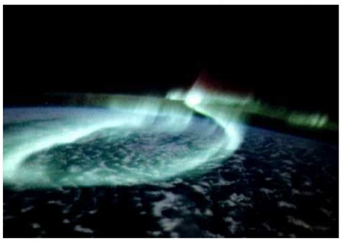
(Video clip of the Sun making a complete circuit of the horizon)

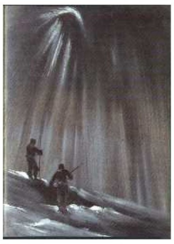
Charged particles (protons, electrons, nuclei):

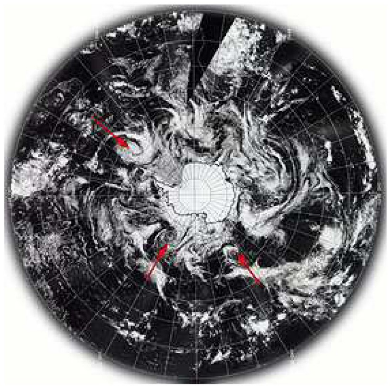
- From Sun - cause aurorae (ionization and recombination of molecules in terrestrial atmosphere)
- *Cosmic Rays* - accelerated to high energies (supernovae? Gamma-ray bursters? Active galactic nuclei?)

Aurora australis

(Southern lights)

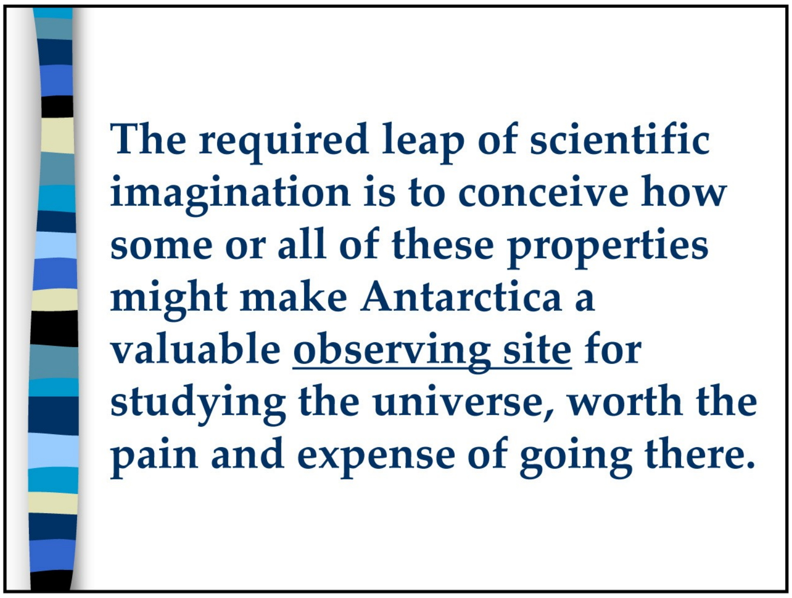






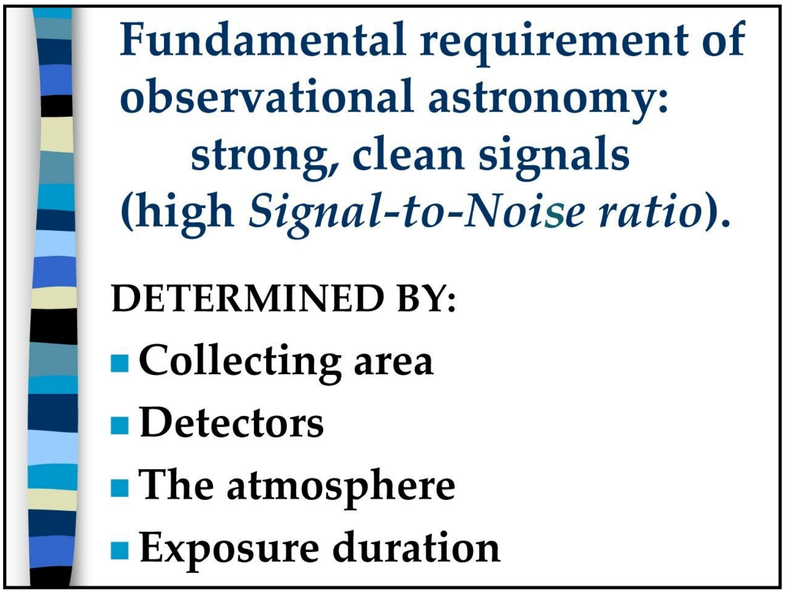
What is *Antarctic Astronomy* (2)?

I can now answer the question :



This is the nub. Natural conditions in Antarctica are exploited in order to get better observations in a cost-effective fashion.

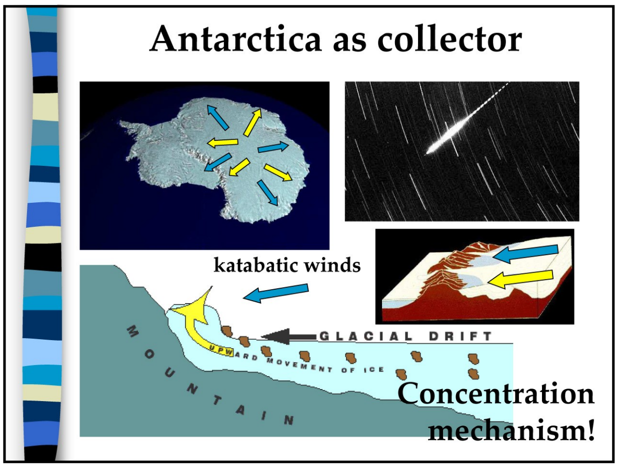
And what does observational astronomy require?

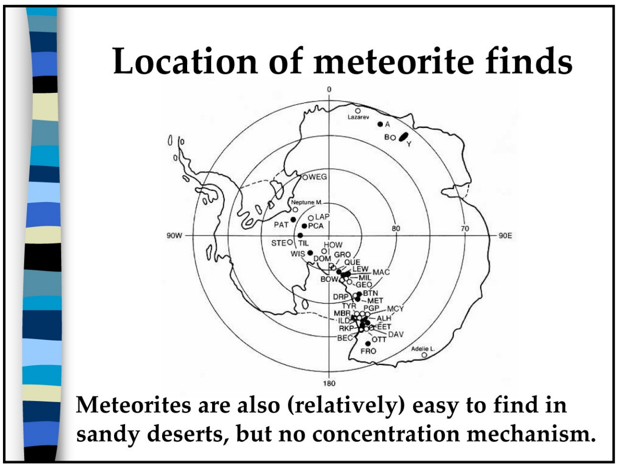


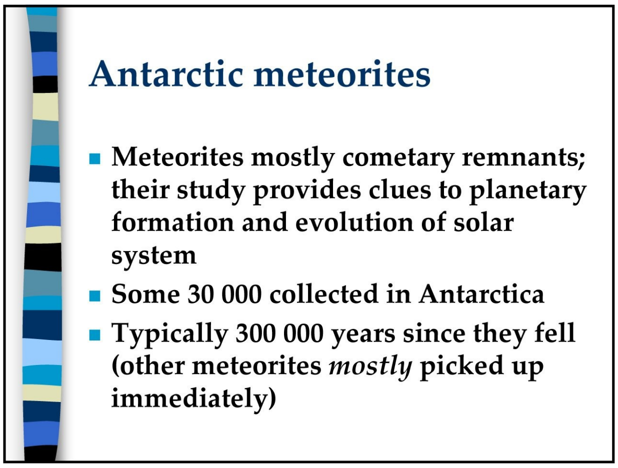
I then turn to some specific opportunities offered by Antarctica with respect to each of these factors.

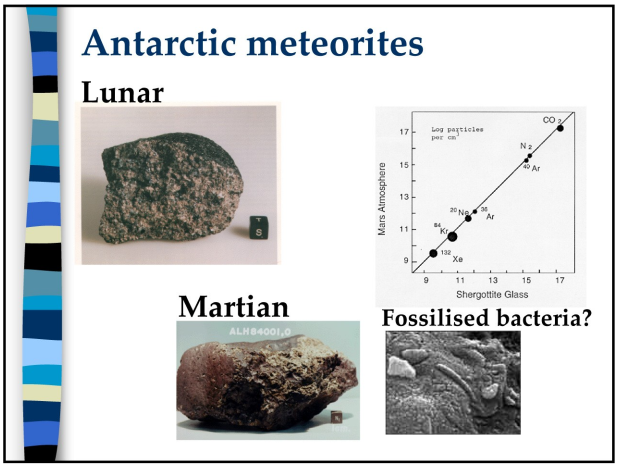
Collecting area

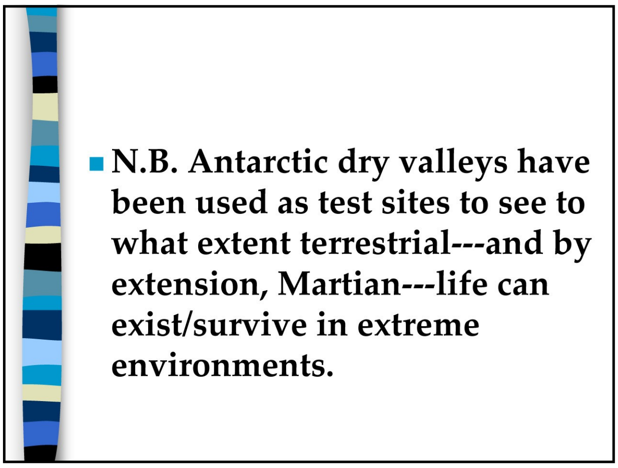
The example given concerns meteorites, which are collected by the ice sheet and concentrated at the Transantarctic mountains by glacial drift.











Antarctica as Detector

The example given concerns neutrinos where Antarctic ice can act as a Cherenkov scintillator because it is abundant and clean. I introduce the important idea of *proof of concept.*

Antarctica as detector

- *Neutrinos* are fundamental particles of very low mass [< 1/2 500 000 mass(electron)] which interact *very* weakly
- Need voluminous detectors
- Undeviated during flight
- Probe deep inside sources

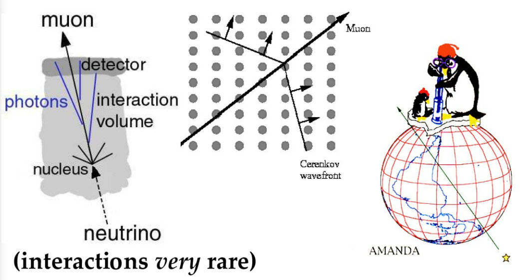
Neutrinos are emitted by:

- Nuclear reactions in Sun
- Same environment that accelerates cosmic rays:
  - supernova explosions
  - gamma-ray bursters
  - active galactic nuclei
- Cosmic-ray collisions with matter e.g. Earth's atmosphere

AMANDA

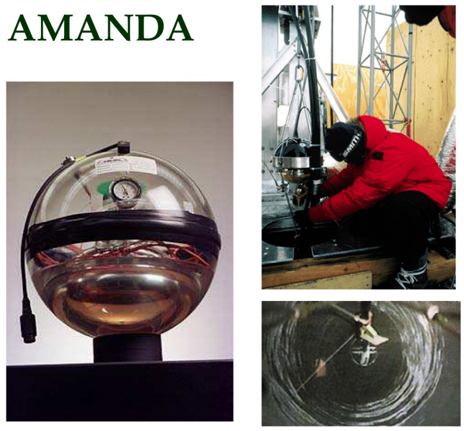
Antarctic Muon And Neutrino Detector Array

Neutrino + nucleus --> muon(±) + other

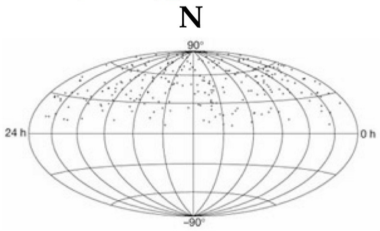


(interactions *very* rare)

AMANDA



288 neutrinos [*Nature* v.410, p.441 (2001)]



These neutrinos generated by Cosmic-Ray collisions in the *northern*-hemisphere atmosphere.

AMANDA provided proof-of-concept.

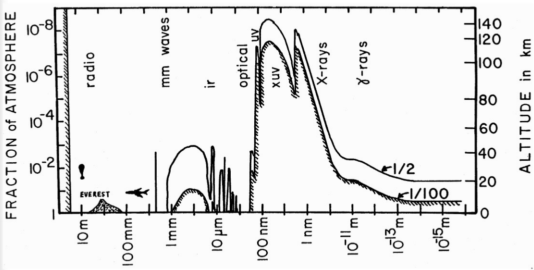
Next stage is to increase detecting area to ~1 sq. km. (AMANDA-II, IceCube) to detect *excess* neutrino flux (i.e. above this background) from discrete cosmic sources.

Also in the holes: RICE (Radio Ice Cerenkov Experiment; even higher energies; Dr Jenni Adams UofC)

The Antarctic Atmosphere

The example I give concerns infrared to sub-millimetre wavelengths and their importance for star formation :

Atmospheric transmission



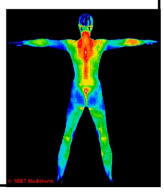
Wavelength

Infrared to sub-millimetre wavelengths (~1μm - ~1mm)

- These wavelengths of great interest for an important question of contemporary astronomy --- star formation (linked to interstellar dust & molecules)

Infrared to sub-millimetre wavelengths (~1μm - ~1mm)

- Antarctic plateau is
  - high ==> less atmospheric absorption
  - dry (only a few cm of precipitable water) ==> less water-vapour absorption
  - scattering free (when no clouds/ice crystals)
  - cold ==> less thermal emission from telescope, atmosphere ('dark skies')

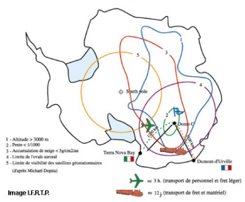


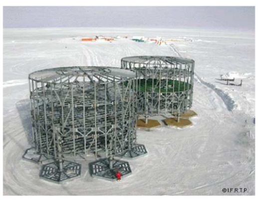
Infrared to sub-millimetre wavelengths (~1μm - ~1mm)

- Antarctic plateau is
  - unturbulent air (stable layers with little wind [*origin* of katabatic winds]) ==> less smearing of angular structure

Infrared to sub-millimetre wavelengths (~1μm - ~1mm)

- Many optical-ir-mm projects at high plateau sites (South Pole, Dome A, Concordia base)

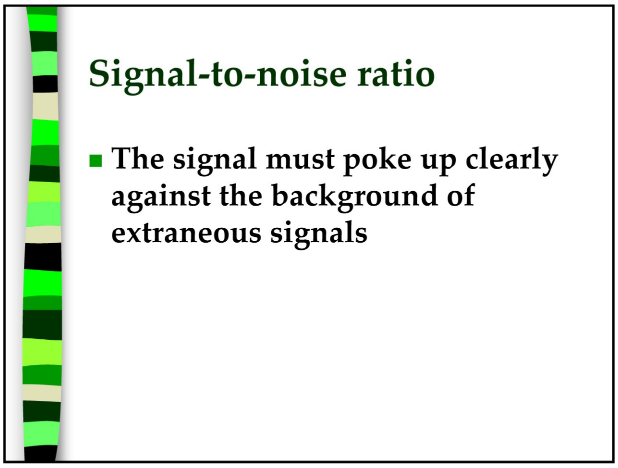


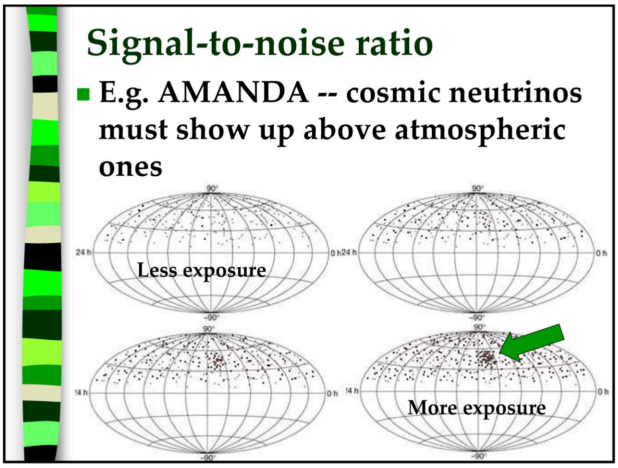


Infrared to sub-millimetre wavelengths (~1μm - ~1mm)

- In a 20-year timescale, can expect to see major, permanent, ir-submillimetre, general-purpose observatories in Antarctica

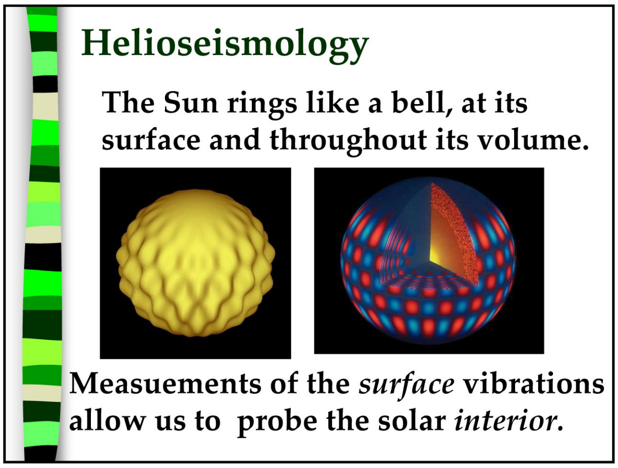
Exposure duration

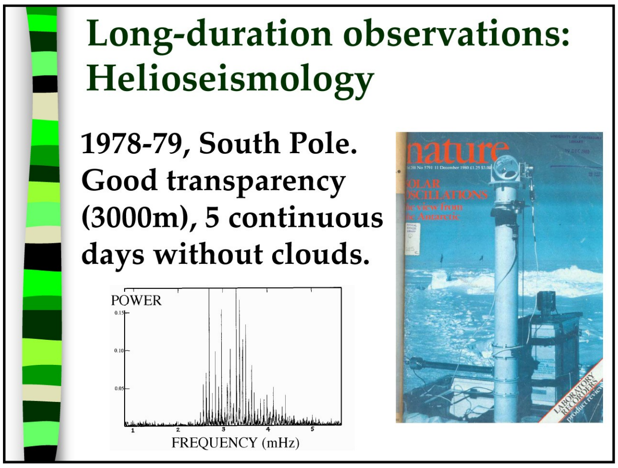


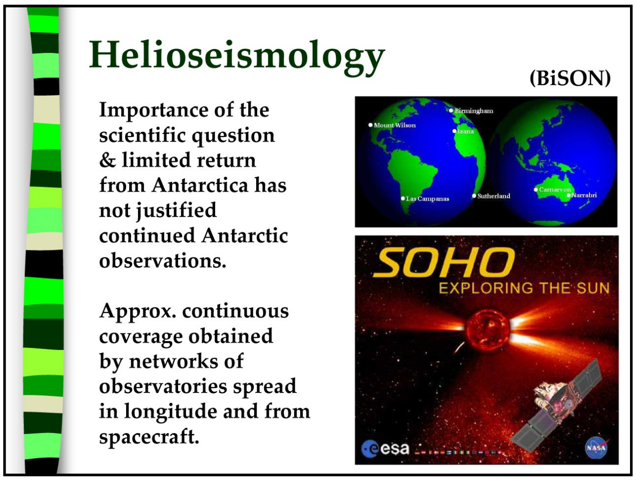


Helioseismology and balloon observations are given as examples where Antarctica permits longer integration times. The low return from Antarctic helioseismology illustrates that Antarctica's advantages are not always sufficient.

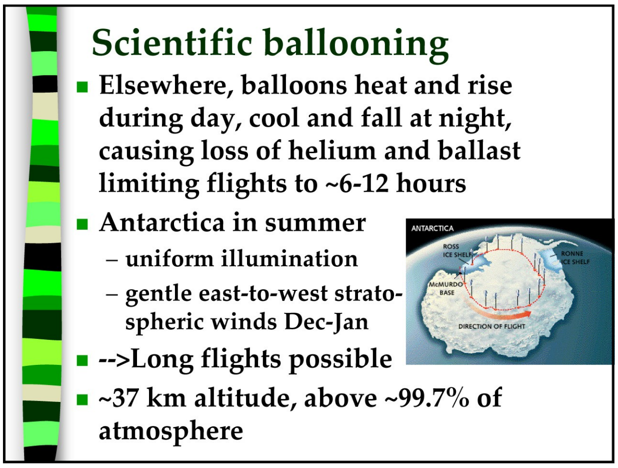
Helioseismology
Long observations during continuous summer daylight

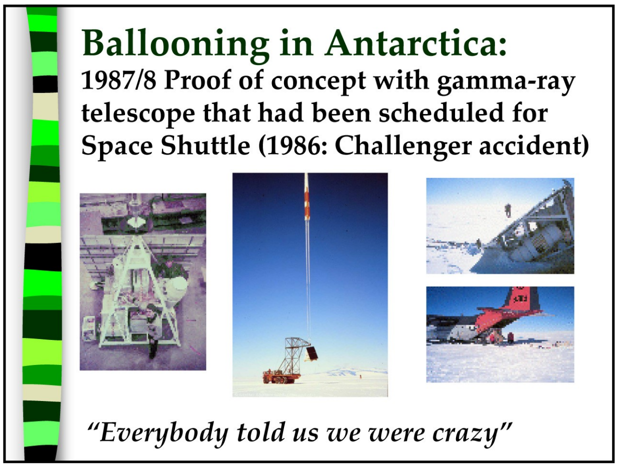


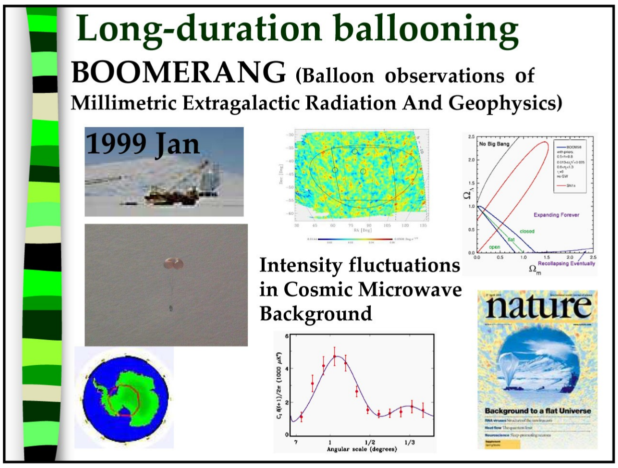


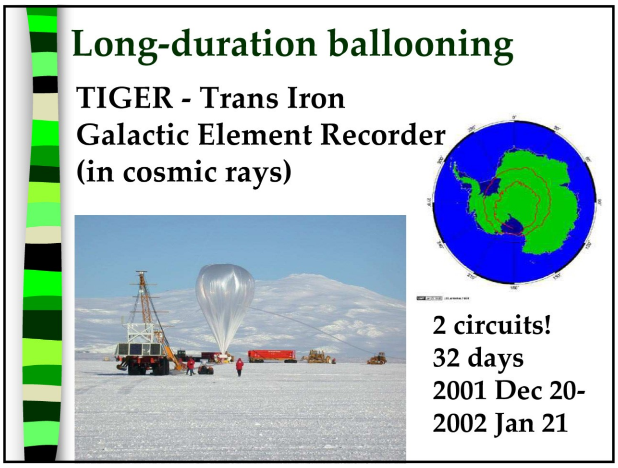


Scientific ballooning
Uniform atmospheric conditions in summer permit long flights; the circumpolar winds bring the balloon back to its launch point.









Conclusion (of the lectures)

Summary

- Examples that have been given are only a small sample of the astronomical activity in Antarctica.
- Many nations involved: Australia, China, France, Italy, Japan, Russia, USA….

Summary

- In appropriate cases, Antarctica offers cost-effective advantages in the four factors crucial to achieving strong, clean signals in observational astronomy
  - collecting area
  - detectors
  - interference, especially by the atmosphere
  - exposure duration

Summary

- Many projects are still at the proof-of-concept stage (e.g. neutrino, infrared and sub-mm observatories)
- Some are mature (e.g. meteorite collection, studies of cosmic rays and the Cosmic Microwave Background)

What did the students think?

PowerPoint (or its OpenOffice equivalent, Impress) is a splendid tool for overview lectures allowing the relatively simple integration of text and multipe images on the same slide. The Web is a fertile source of relevant images, and the presentation can be edited easily. Students raised in an electronic age expect the 'edu-tainement' aspect of PowerPoint and in their course evaluations reject older forms of presentation as hopelessly antiquated.

The principal point I was trying to make in my Antarctic Astronomy lectures was *why* astronomers are going to the Southern Continent; details of *what* they are doing there were secondary, and provided only to illustrate the wider point. From responses in examinations, it is clear that some students grasped this distinction while others did not. (This inability to distinguish the wood from the trees has been called "mental dazzle" and is to be avoided in teaching and grant applications alike.) However the large and assiduous attendance at 8 a.m. indicates students' captivation by the romance and excitement of Antarctica. This captivation may be particularly intense in Christchurch because of the city's long link with Antarctic operations, but I suspect it is widespread and should be cultivated by researchers seeking support for their activities in Antractica.

Download this poster

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http://www2.phys.canterbury.ac.nz/~wjt23/TobinRoscoffPoster.pdf

Some New Zealand Antarctic websites

www.anta.canterbury.ac.nz	Gateway Antarctica
www.antarcticanz.govt.nz	Antarctica New Zealand
www.heritage-antarctica.org	Antarctic Heritage Trust
www.antarctic-link.org.nz	Antarctic Link Canterbury