The SANAP Cosmic-Ray Neutron Monitor Programme

Harm Moraal

North-West University
Potchefstroom

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

SANAP Symposium, 4-5 June 2014

Our group

1. Harm Moraal - PI
2. Helena Krüger - Co-I
3. Gert Benadé – electronics engineer
4. Anne Mans – data and station manager
5. Godfrey Mosotho – M.Sc. student
6. Renier Fuchs – M.Eng. student
7. Ruan Nel – M.Eng. student
8. Henrdik Krüger – expedition member SANAE

Pieter Stoker – Emeritus and founder

Cosmic Rays

- Charged particles - 90% protons, 5% He nuclei, 3% heavier atomic nuclei, 2% electrons

- Characterised by very high energies (10^6 - 10^{20} eV)

One particle = cricket ball at 140 km per hour.

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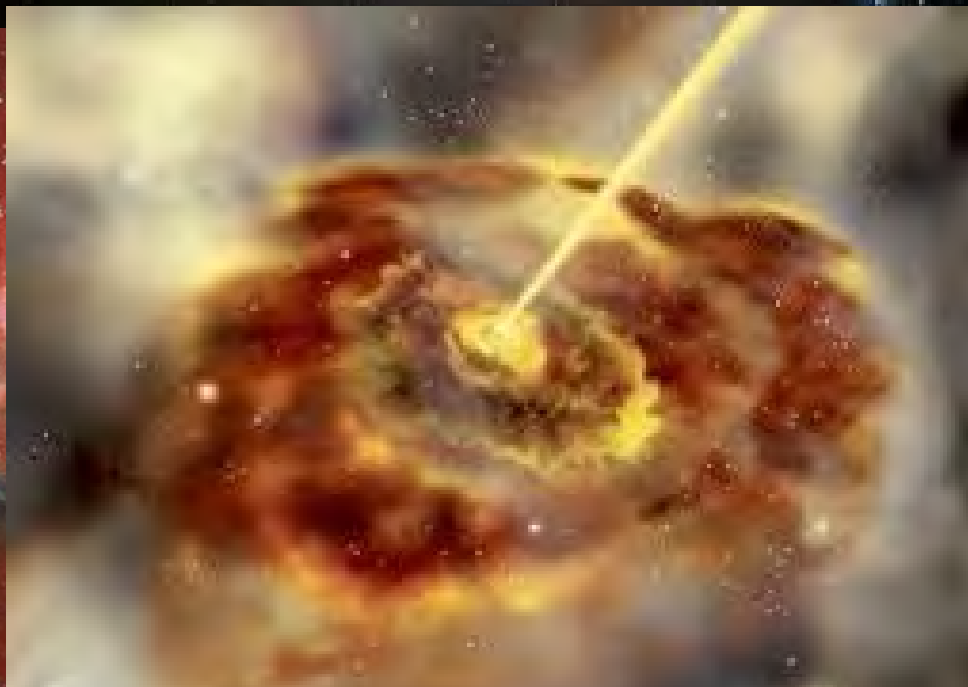
!

Come from the Cosmos ……..

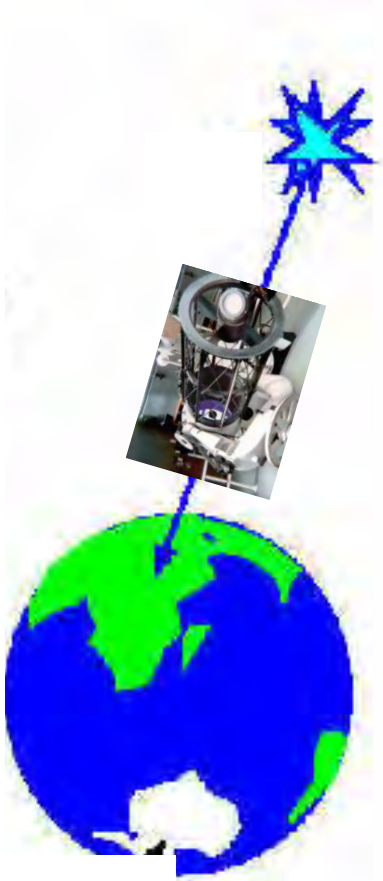


Particle vs. Photon Astronomy

Photons

1. **Where**
2. **How bright**
3. **Colour**

Particle vs. Photon Astronomy



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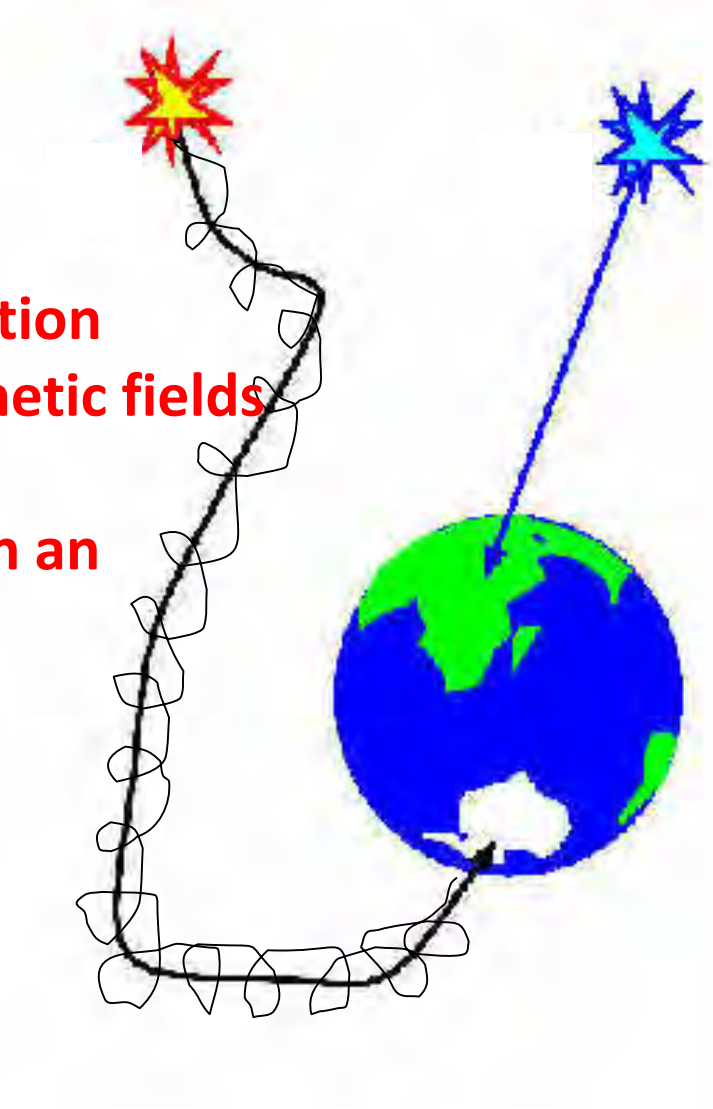
Particle vs. Photon Astronomy

Particles:
No such information
Because of magnetic fields

……like a bead on an elastic band



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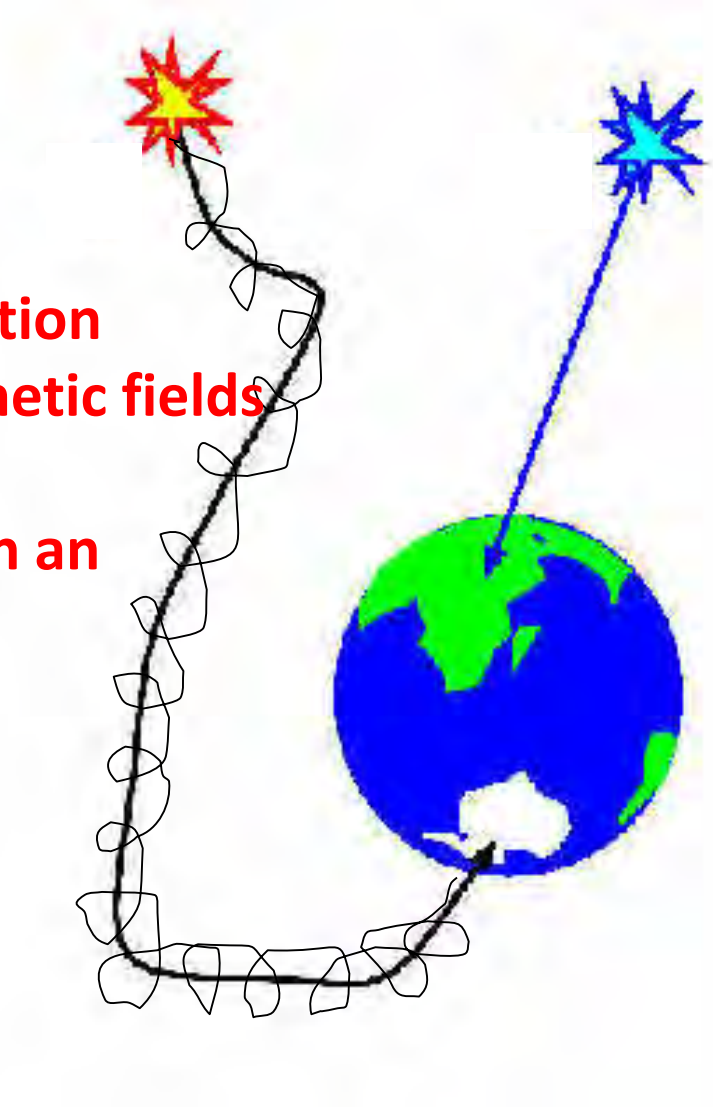


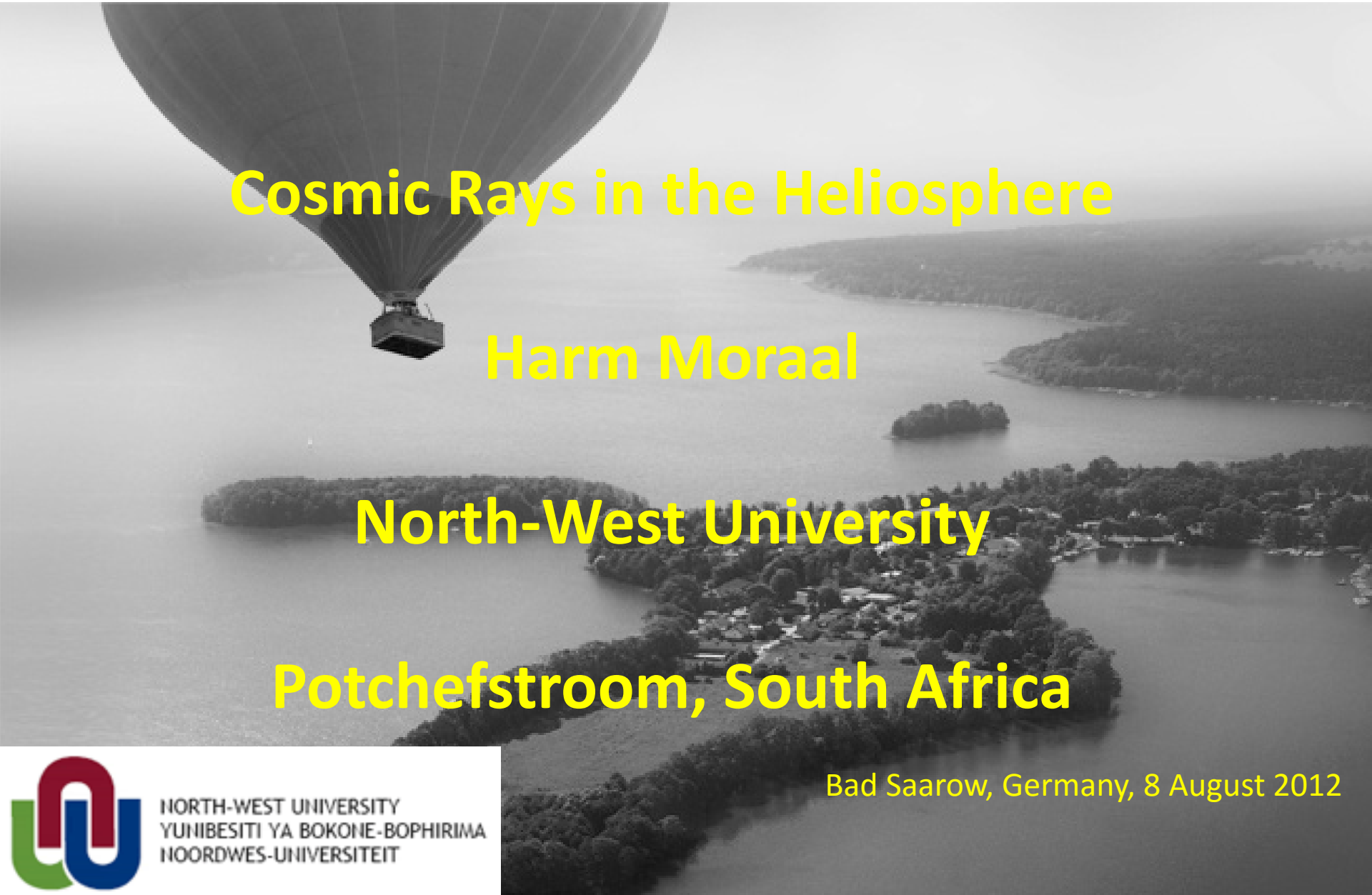
Photons

1. **Where**
2. **How bright**
3. **Colour**

Victor Hess, 7 August 1912

Victor Hess, 7 August 1912

100 years later (+2)



Cosmic Rays in the Heliosphere

Harm Moraal

North-West University

Potchefstroom, South Africa

Bad Saarow, Germany, 8 August 2012

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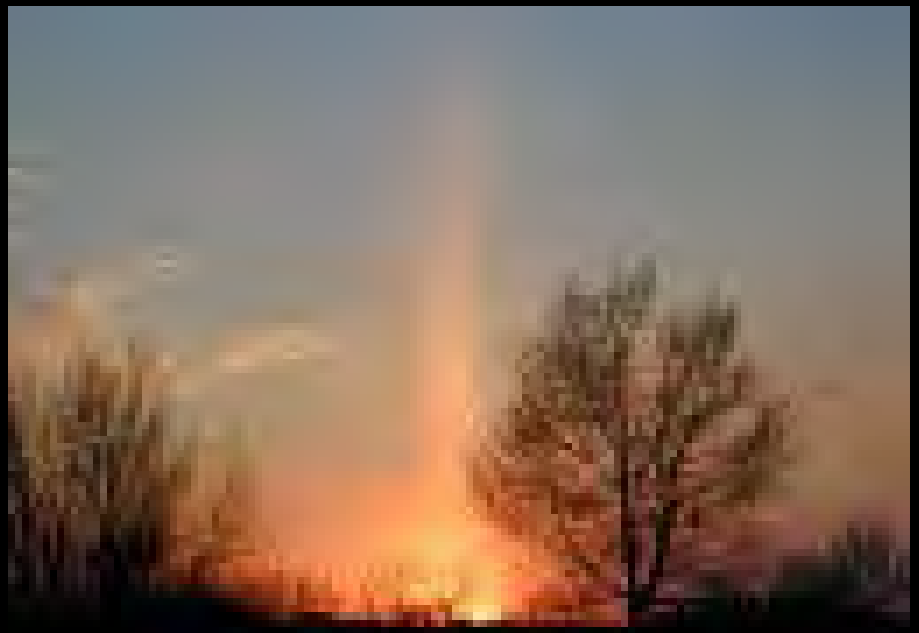
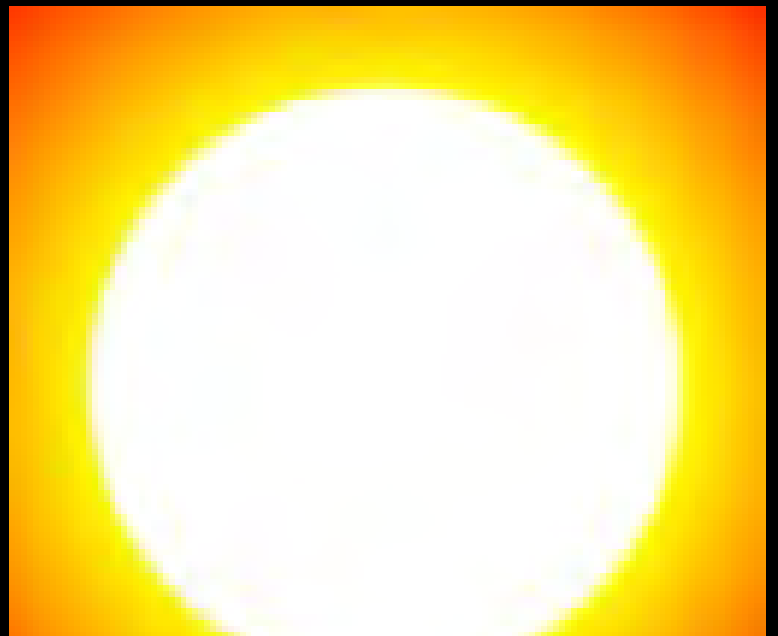
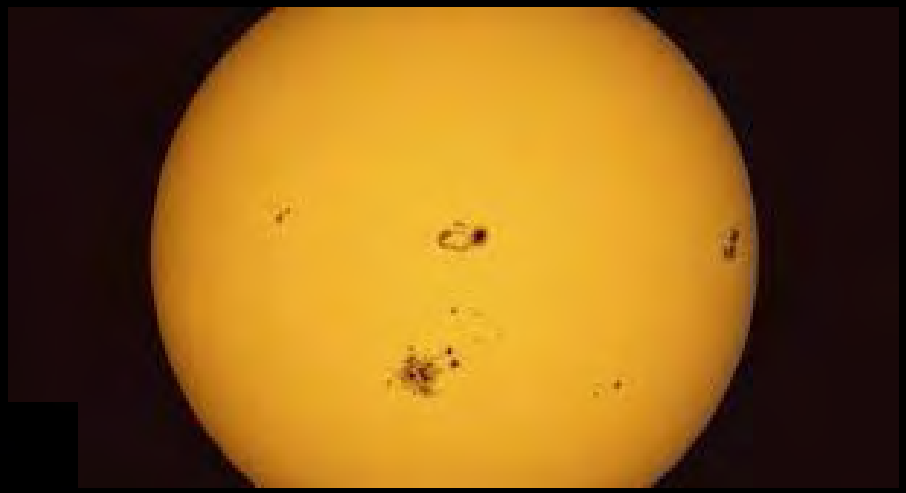
Bad Saarow Railway Station

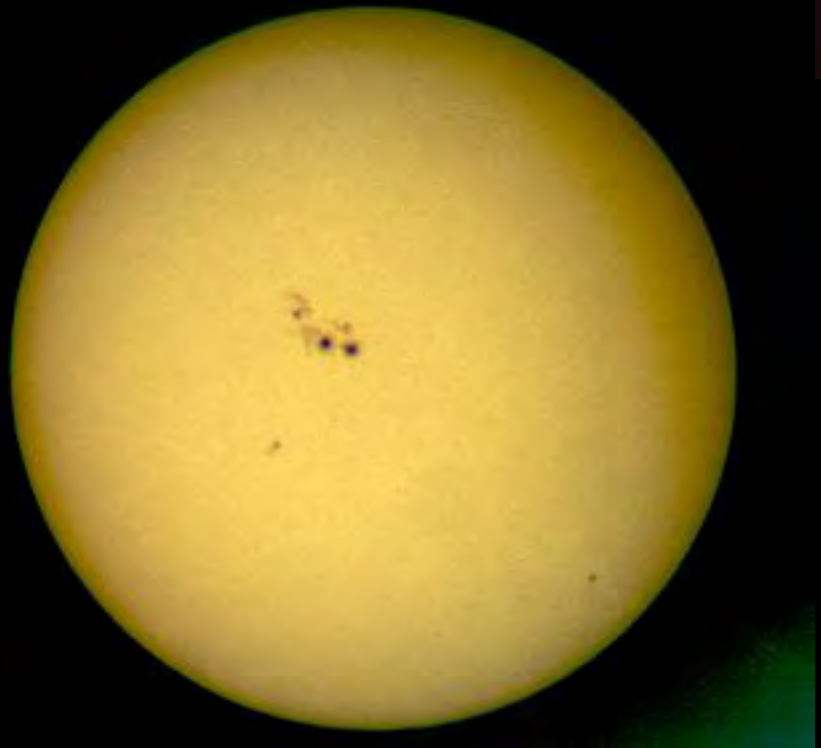
The Sun

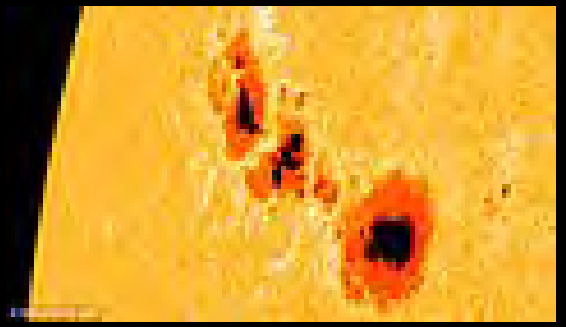




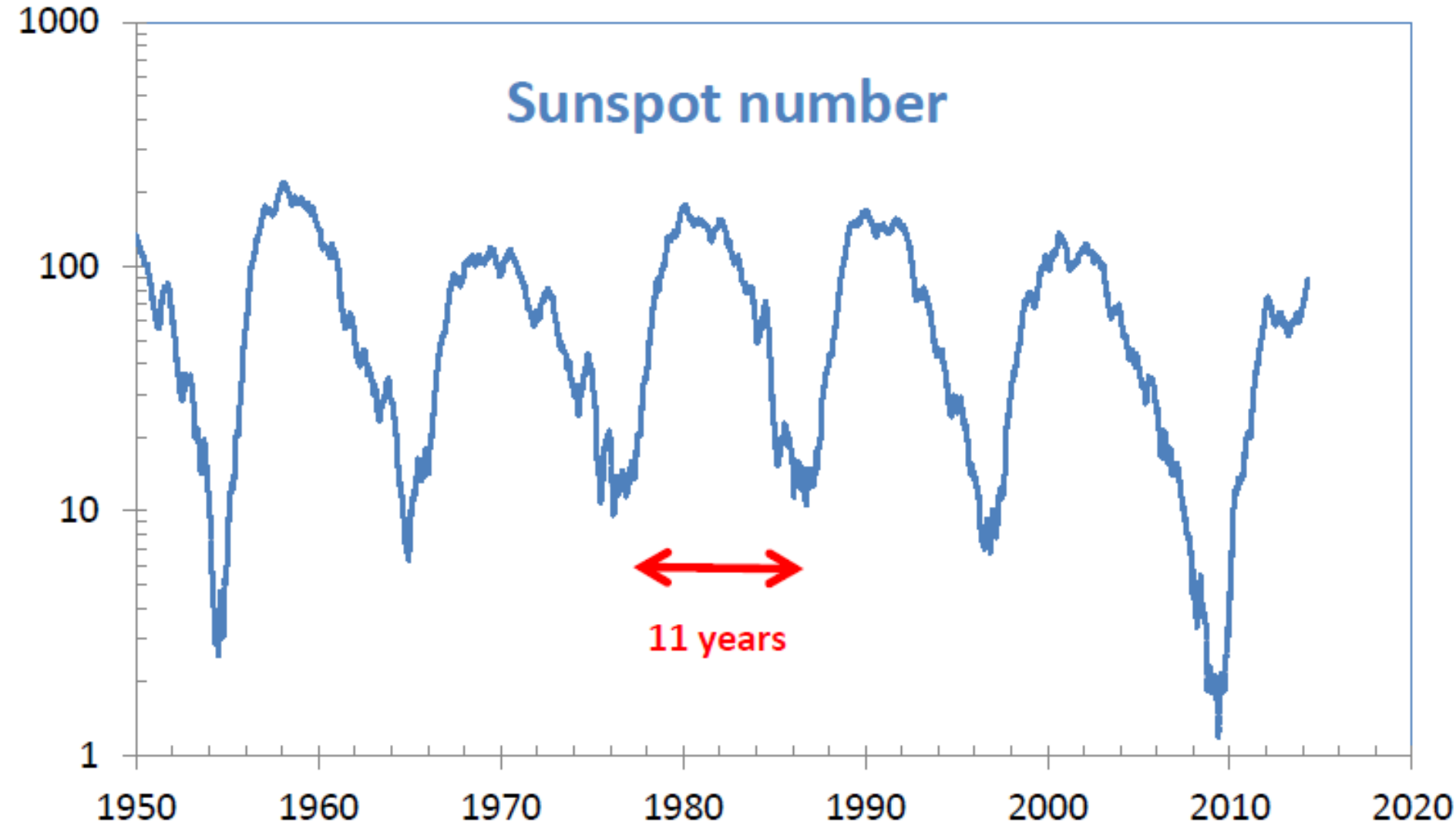
Sunspots



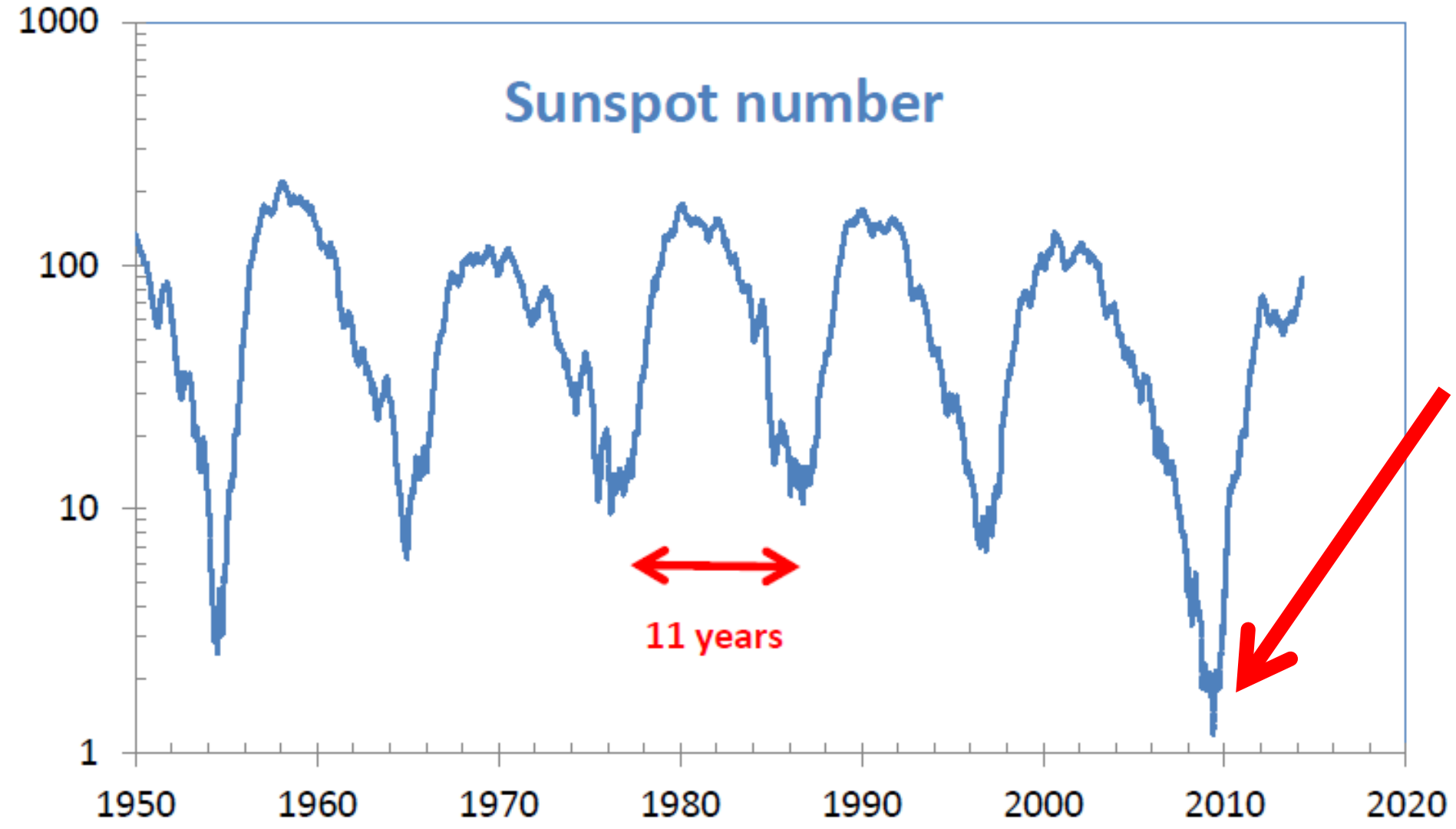




Sunspots


Sunspot number
1000
100
10
1
11 years
1950
1960
1970
1980
1990
2000
2010
2020

Sunspots


Sunspot number
1000
100
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1950
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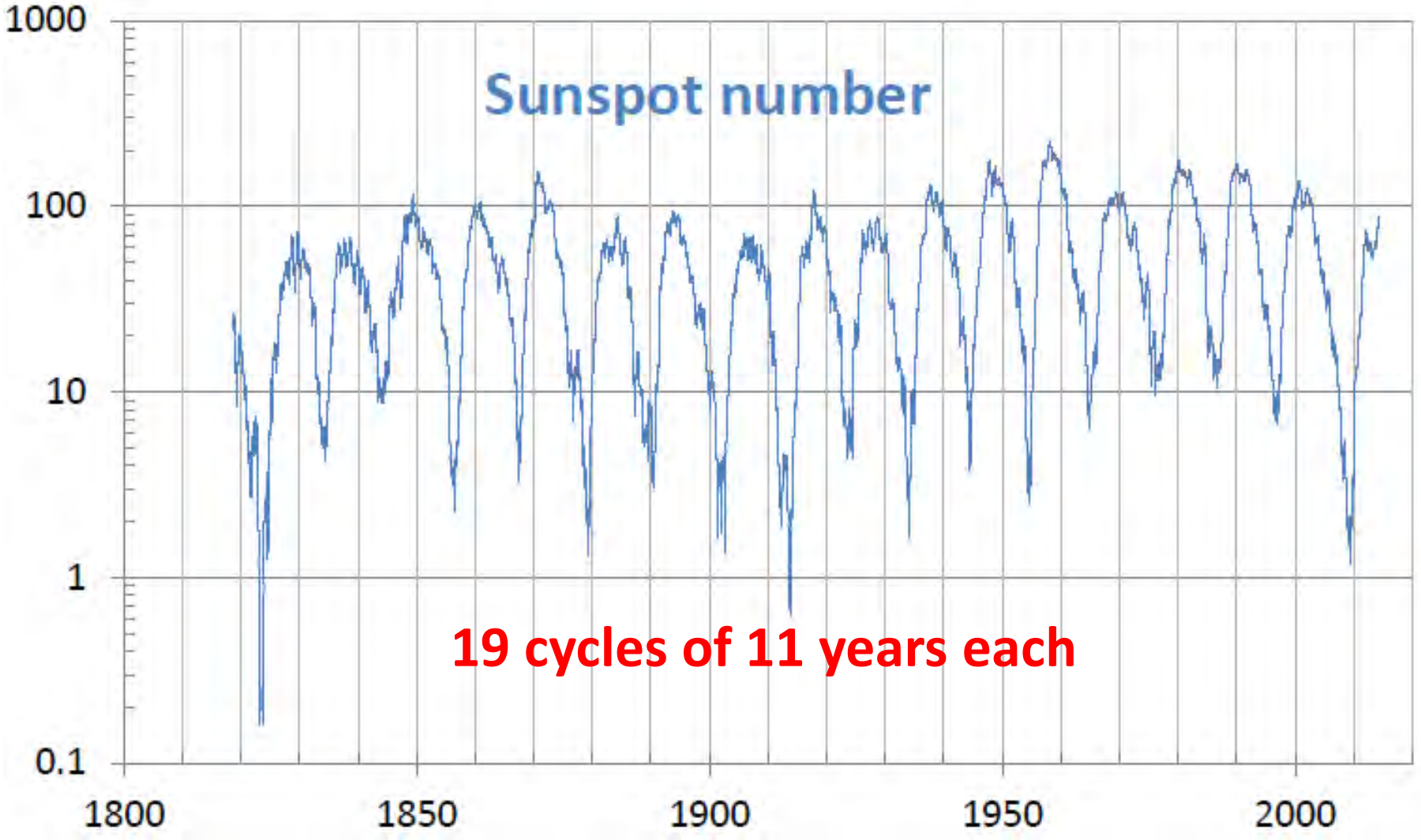
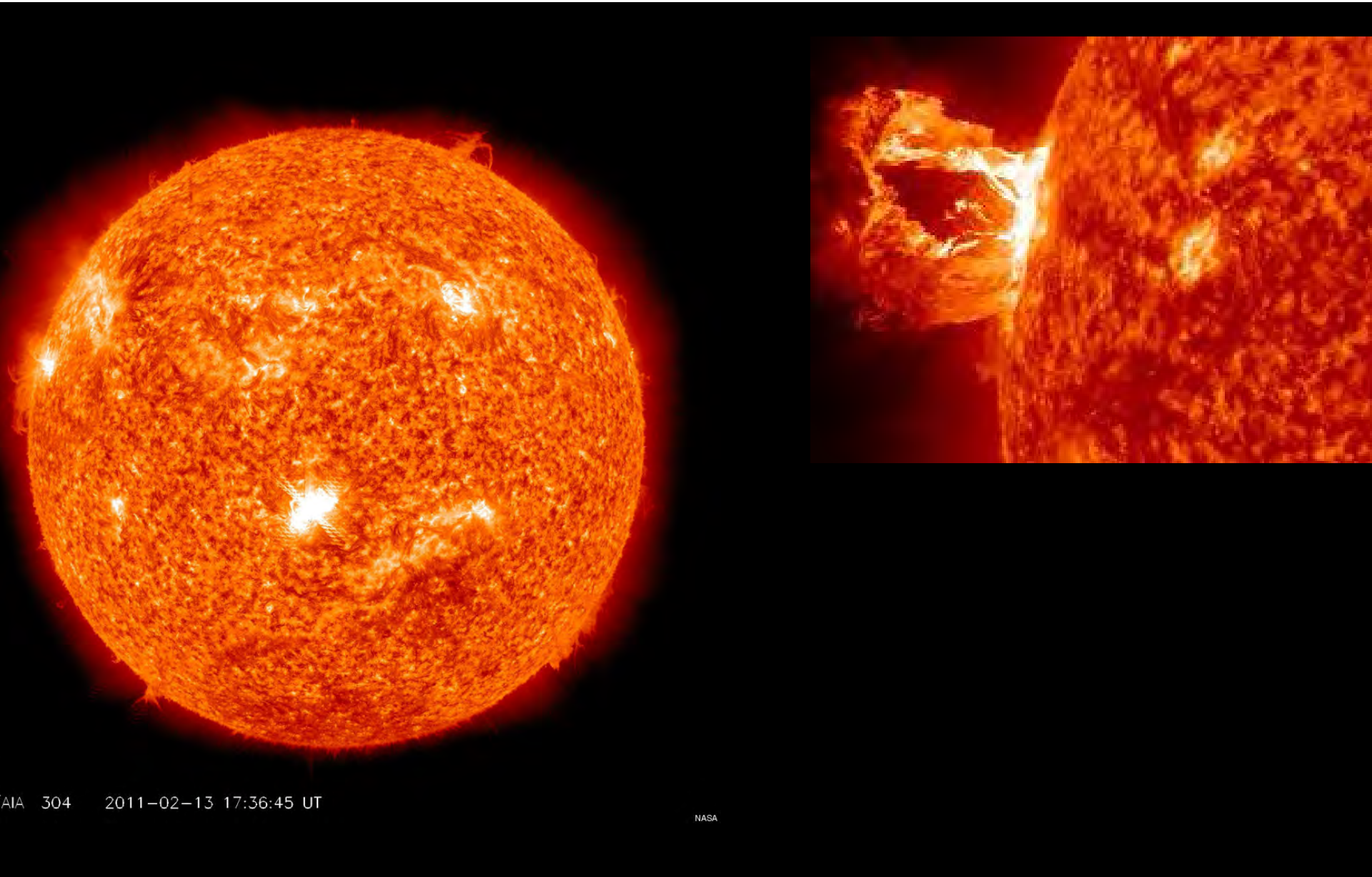
2010
2020
11 years

Sunspots since 1818



Solar Flare



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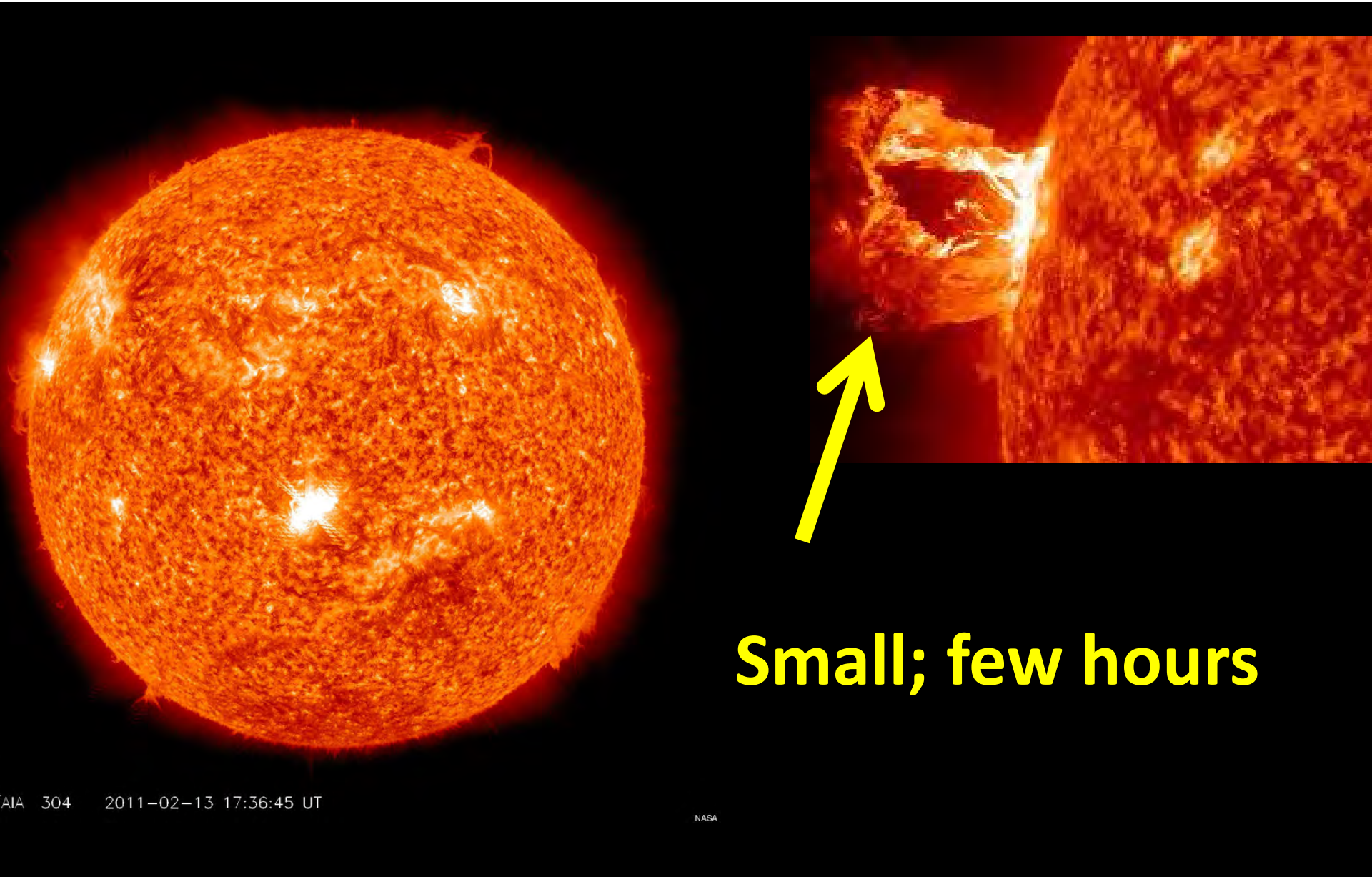
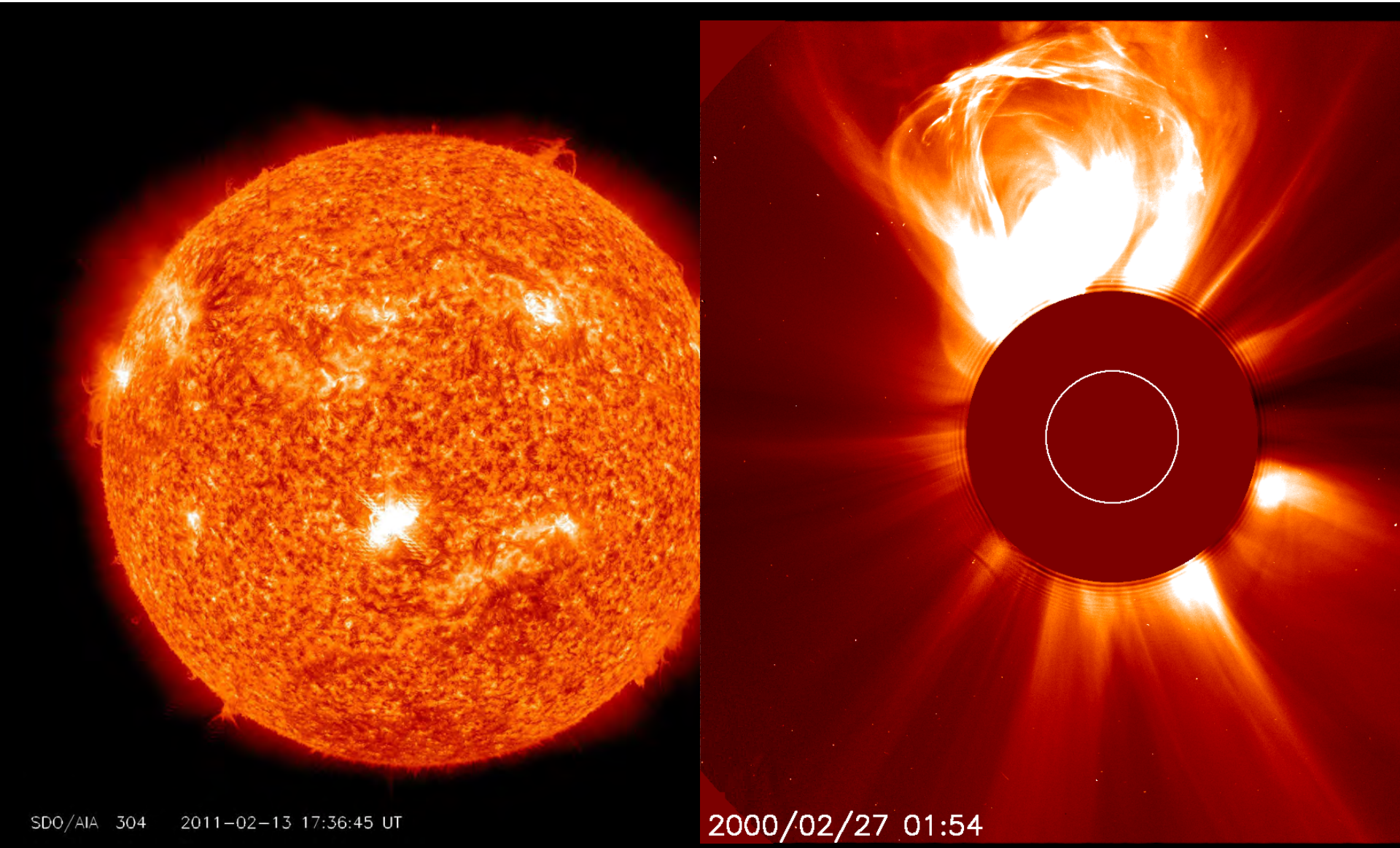
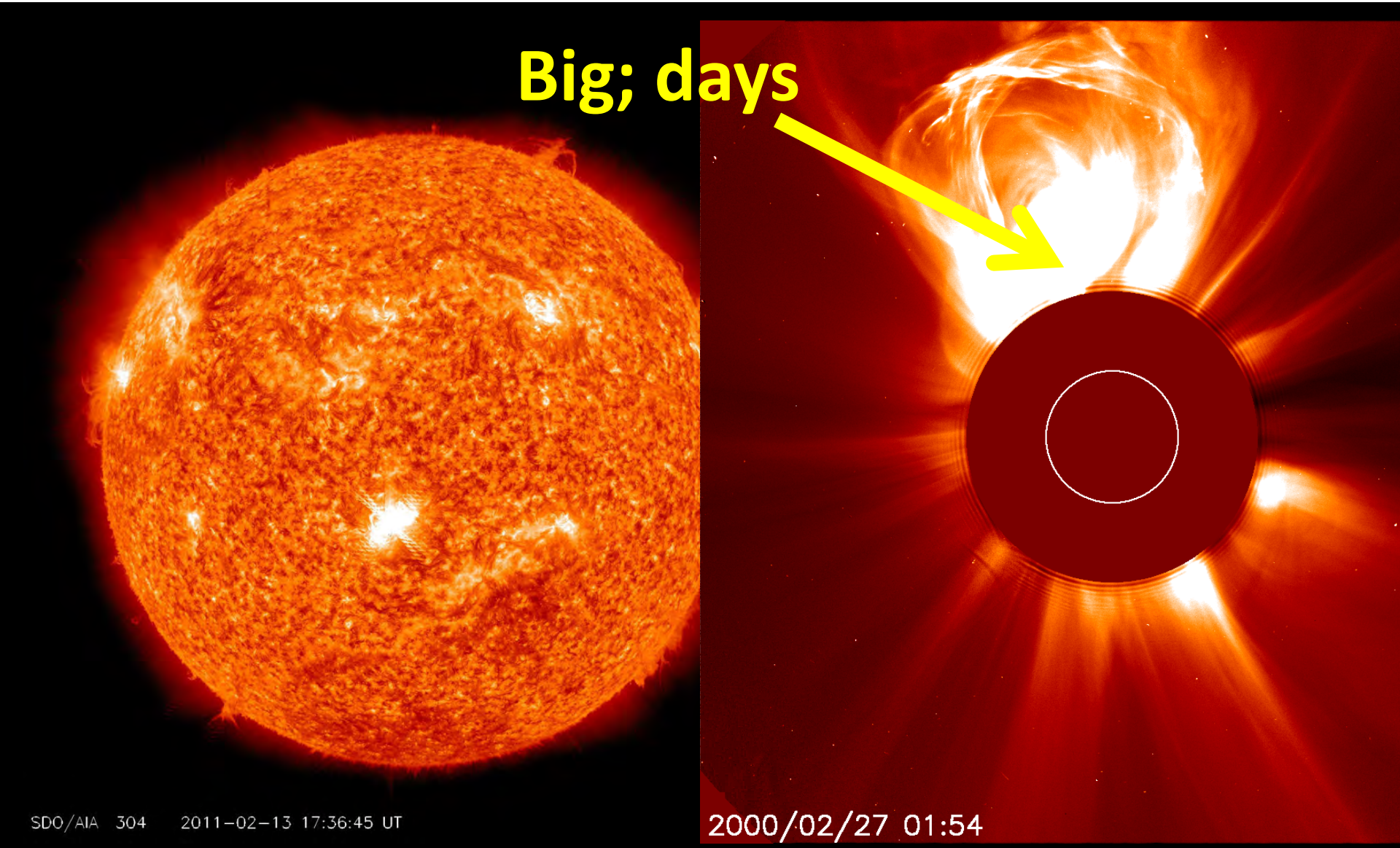


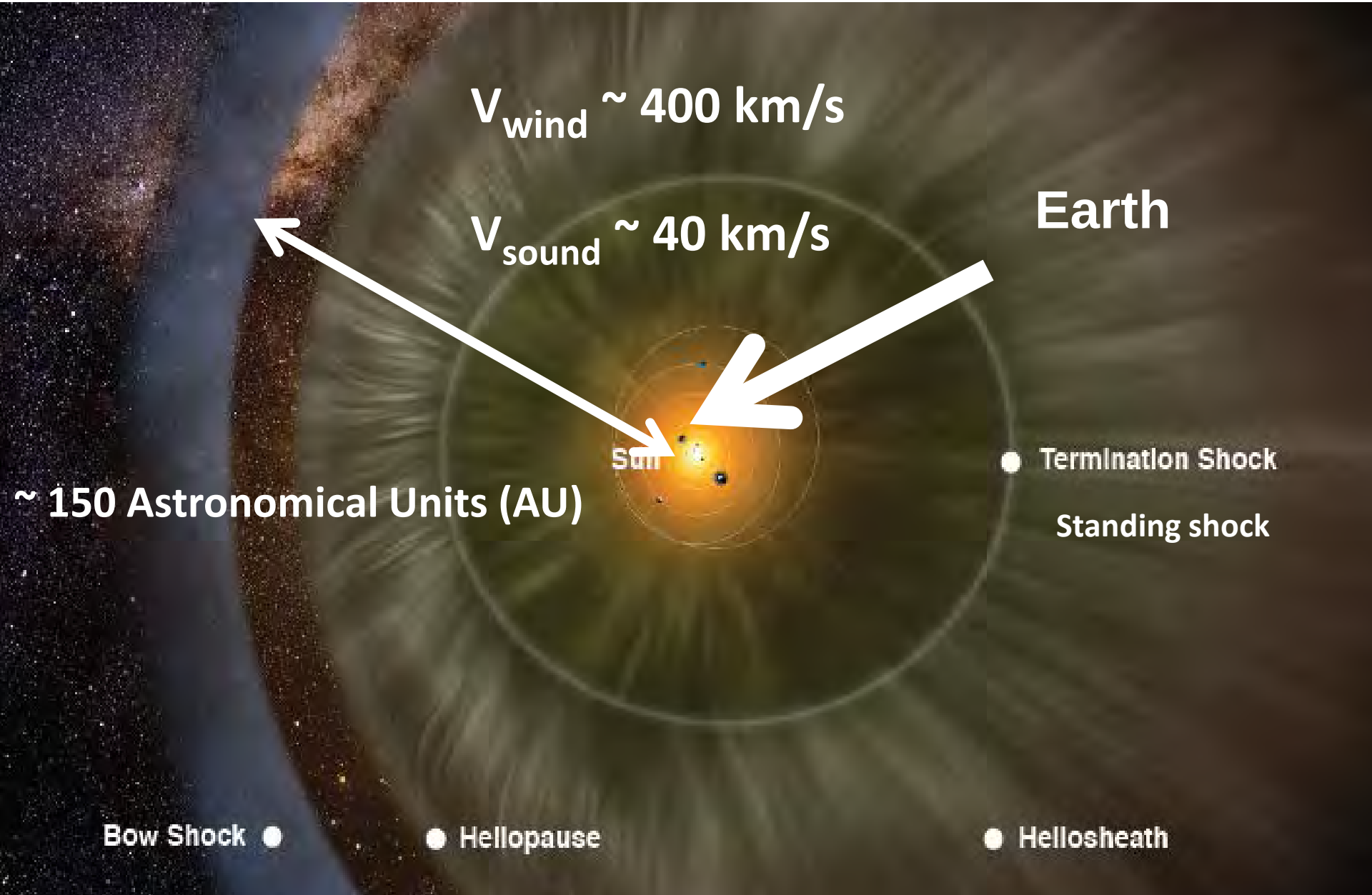
Coronal Mass Ejection



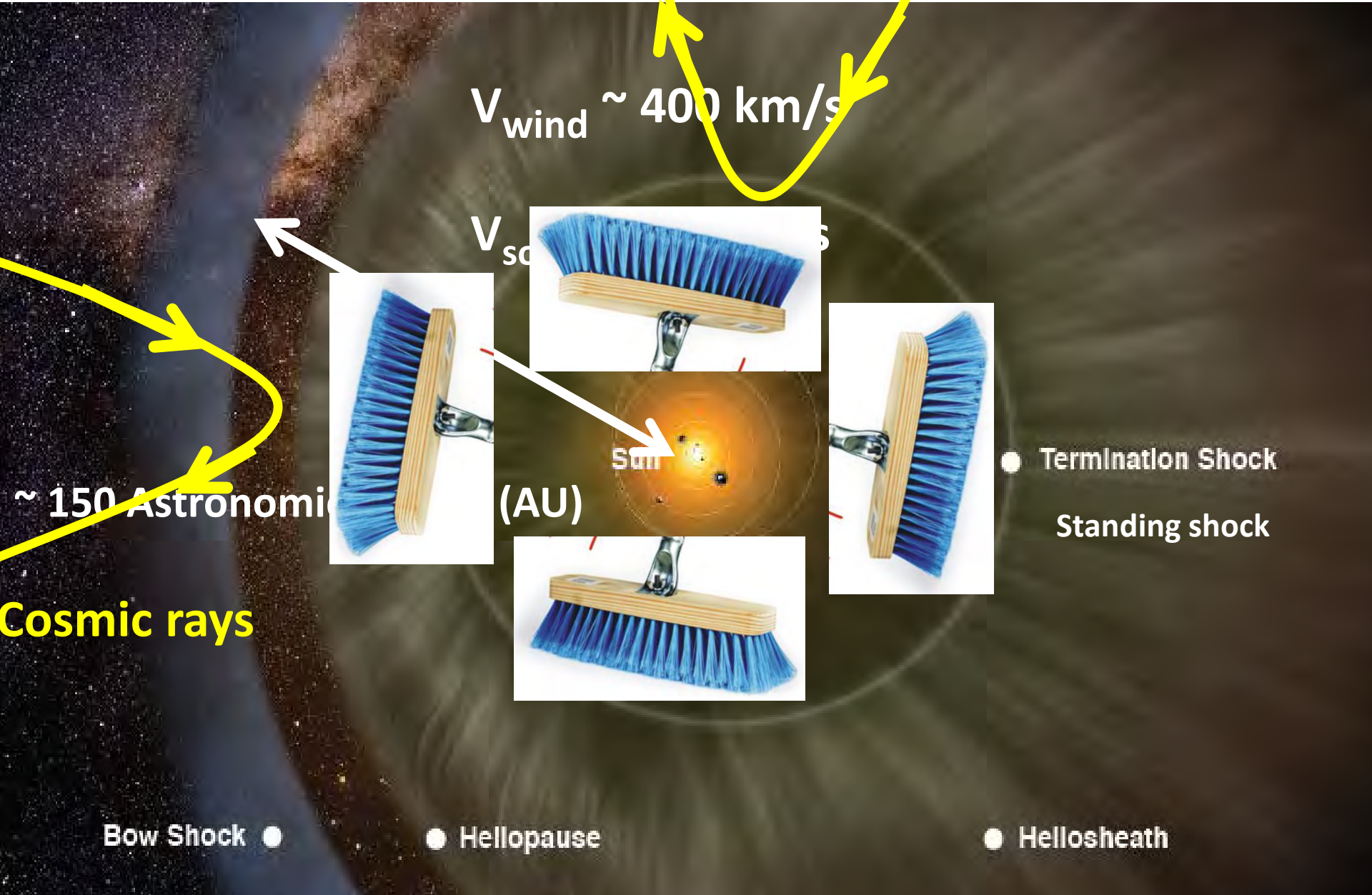
Coronal Mass Ejection



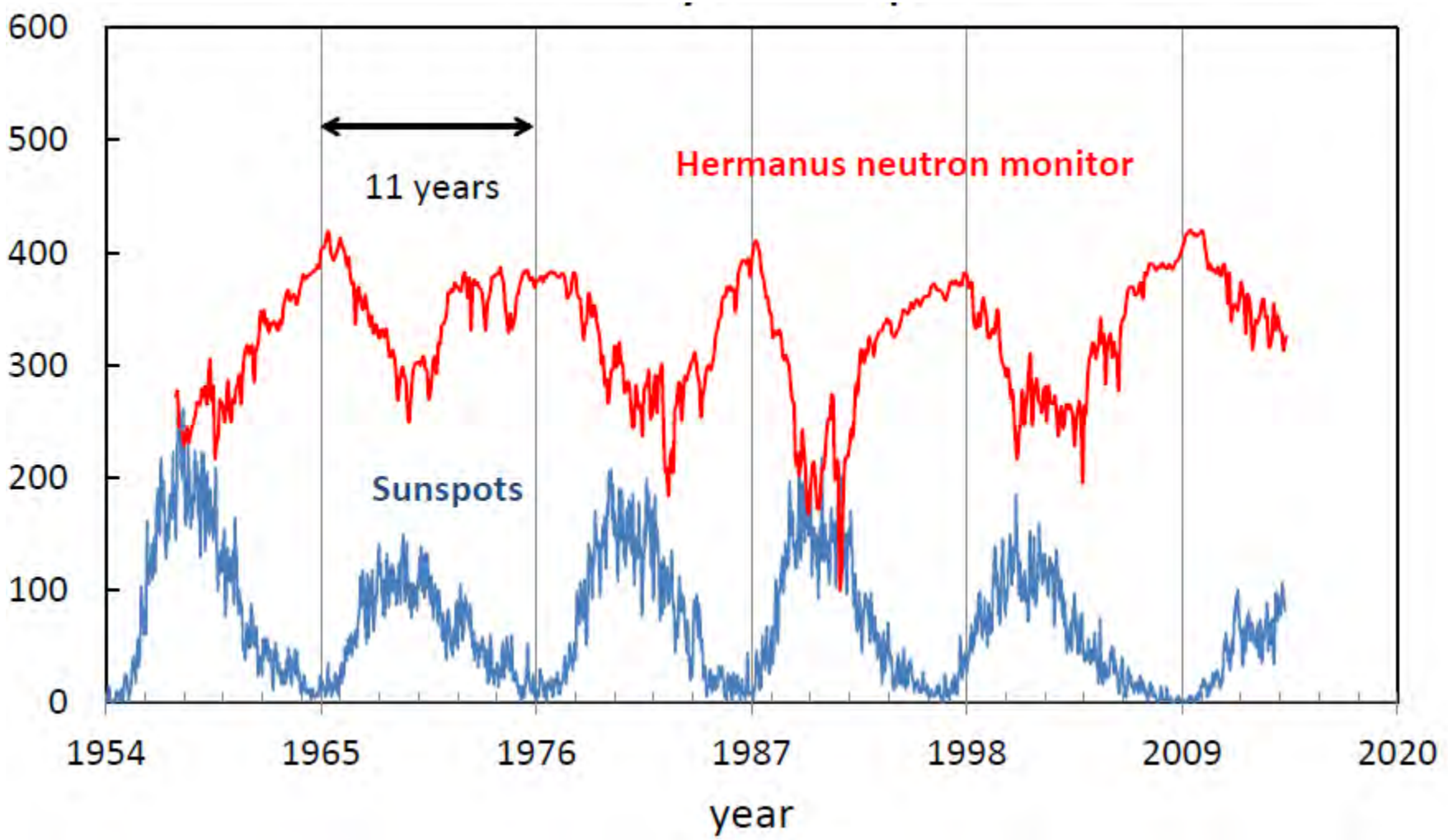
The Solar Wind and Heliosphere



The (variable) broom



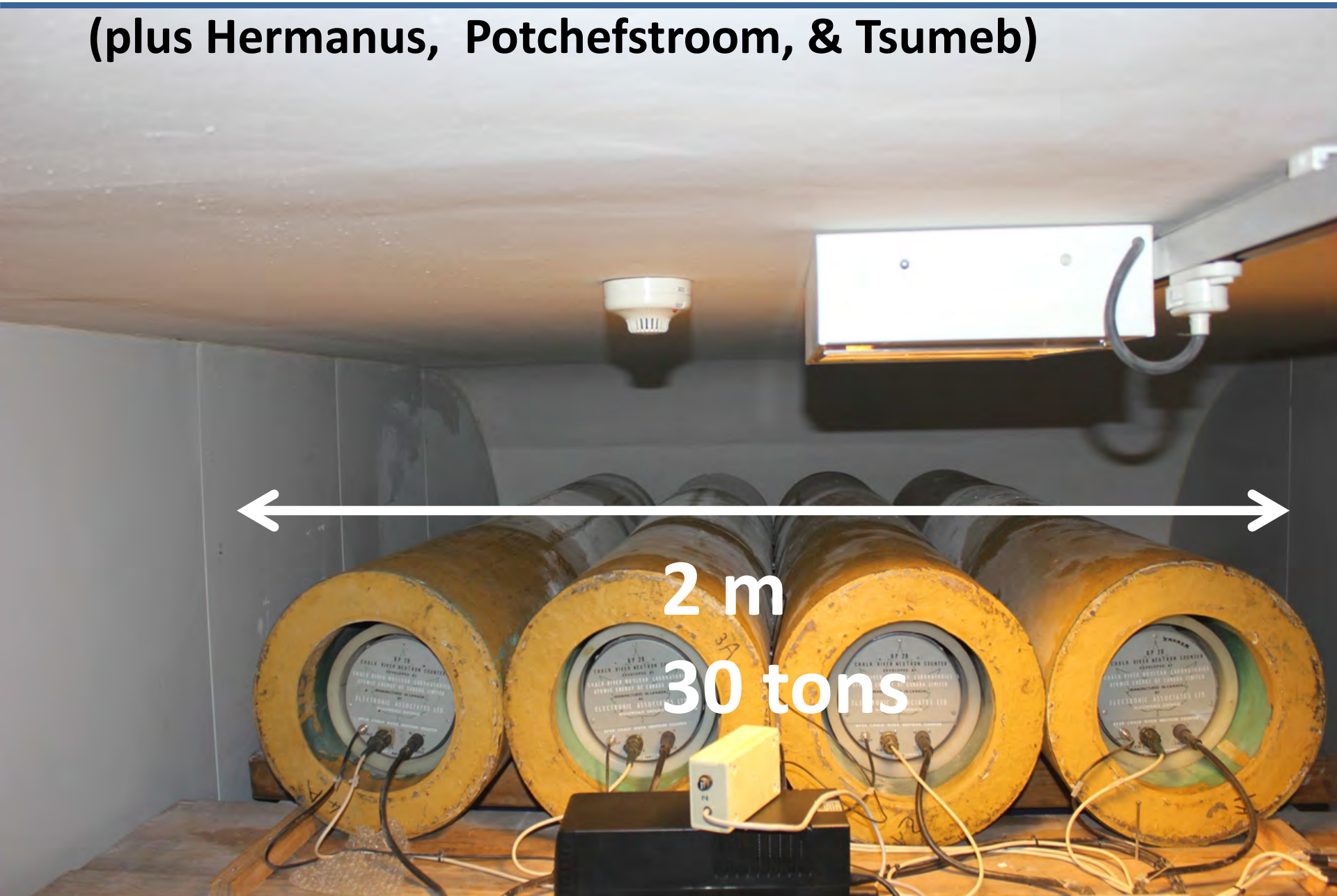
Cosmic rays and sunspots



Sanae Neutron Monitor

Sanae Neutron Monitor

(plus Hermanus, Potchefstroom, & Tsumeb)



Mini neutron monitors

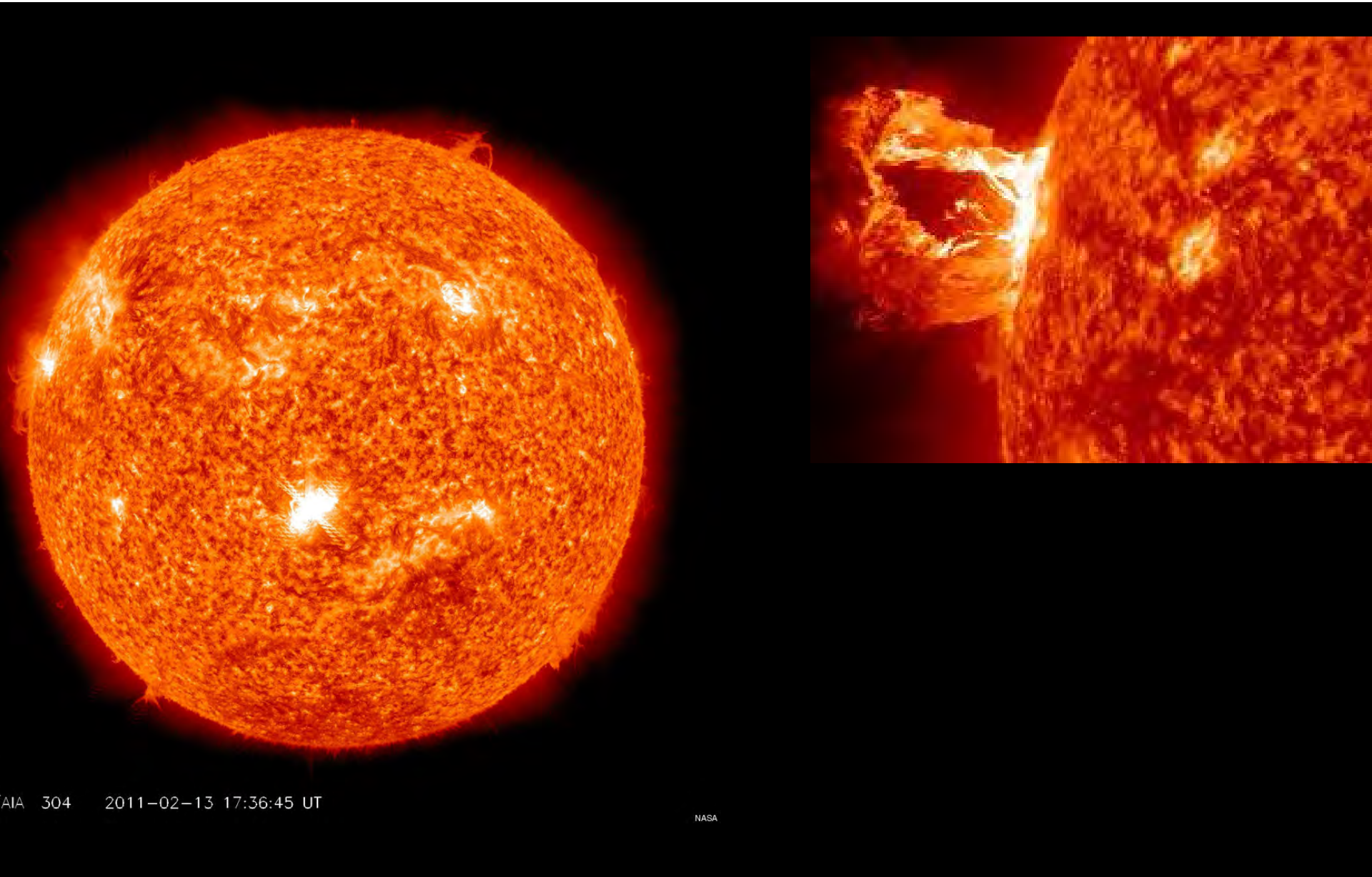
Polarstern

Mini neutron monitors

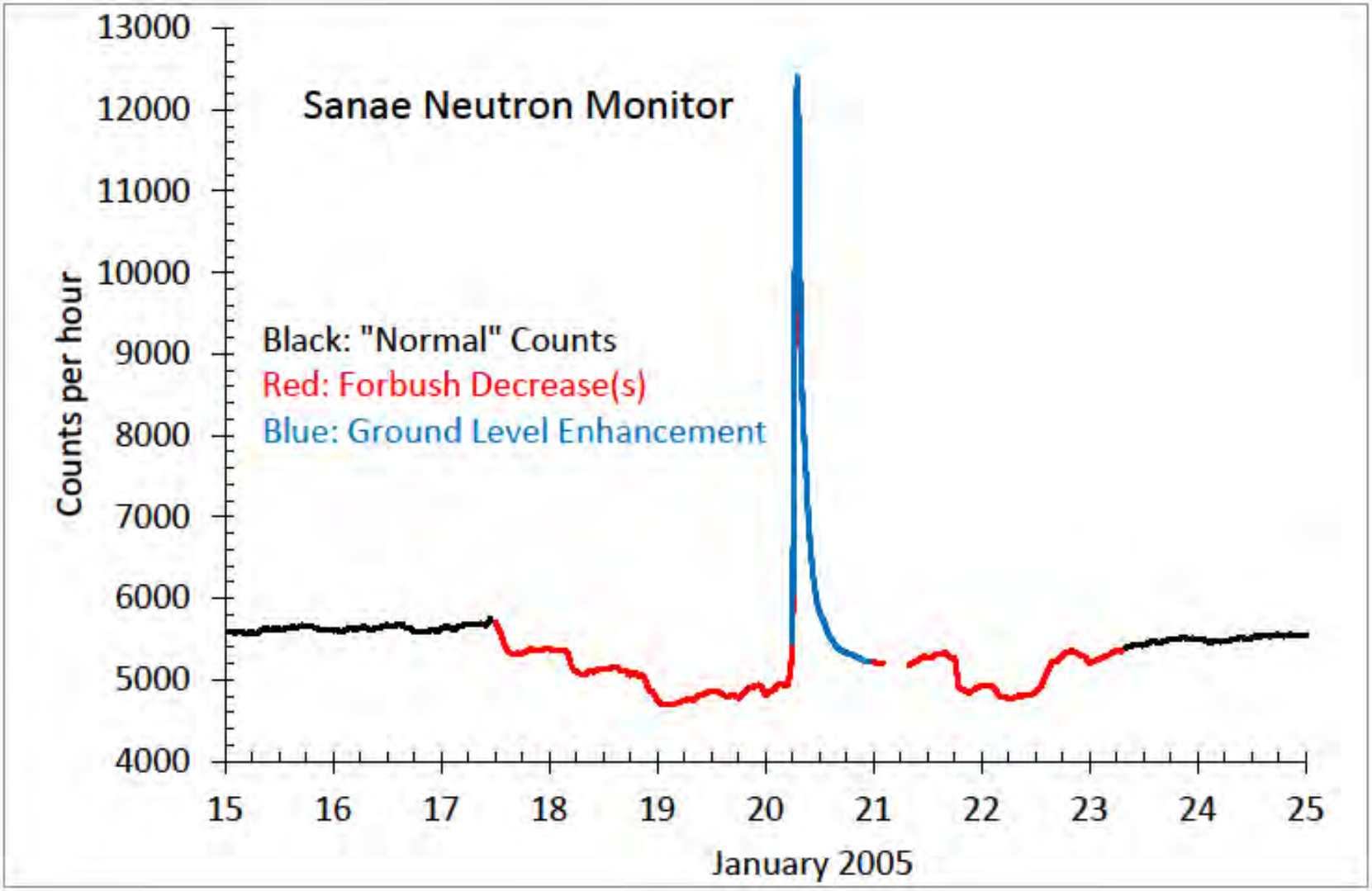
Polarstern

Posters
Gert Benadé

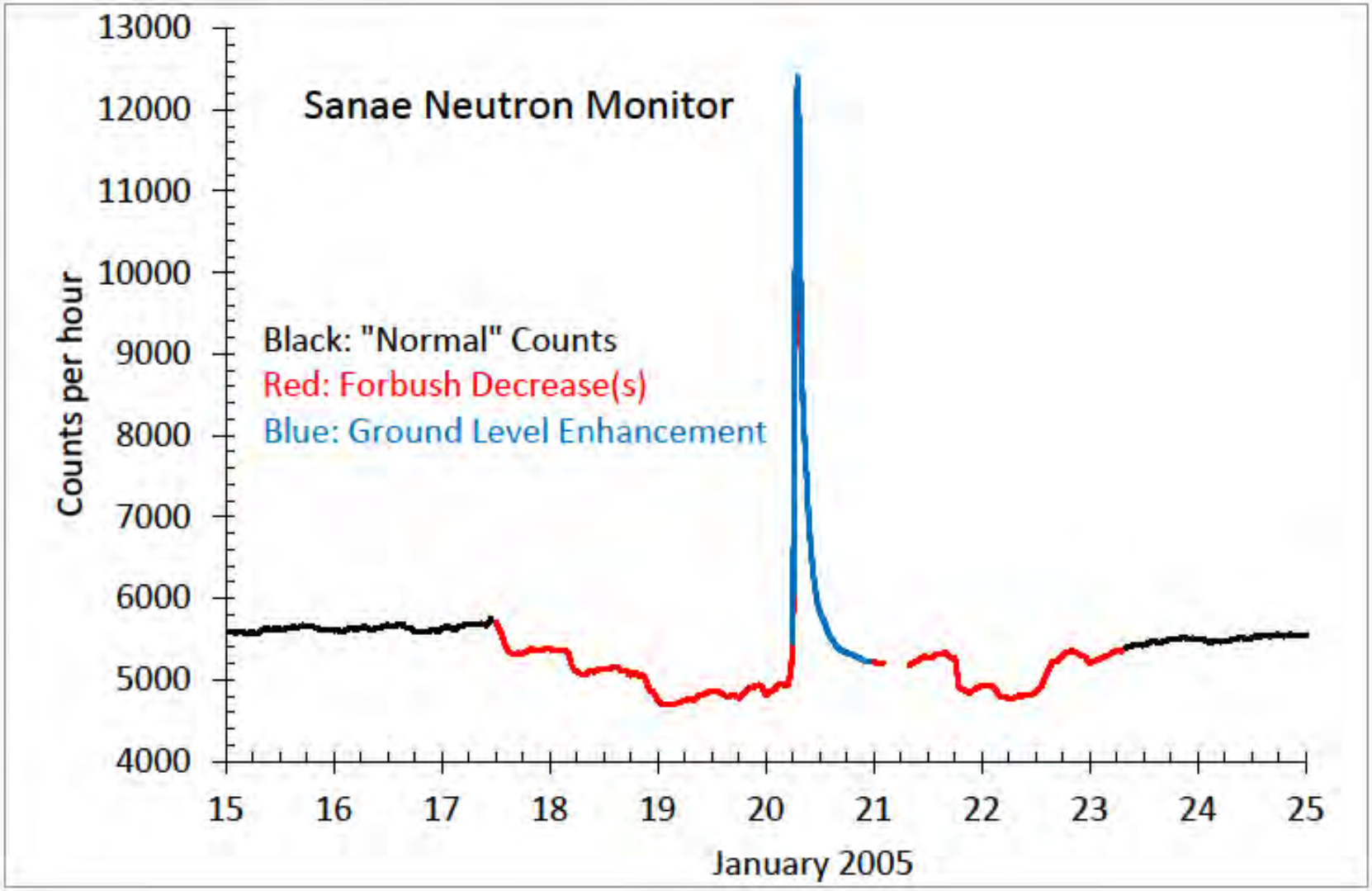
Solar Flare



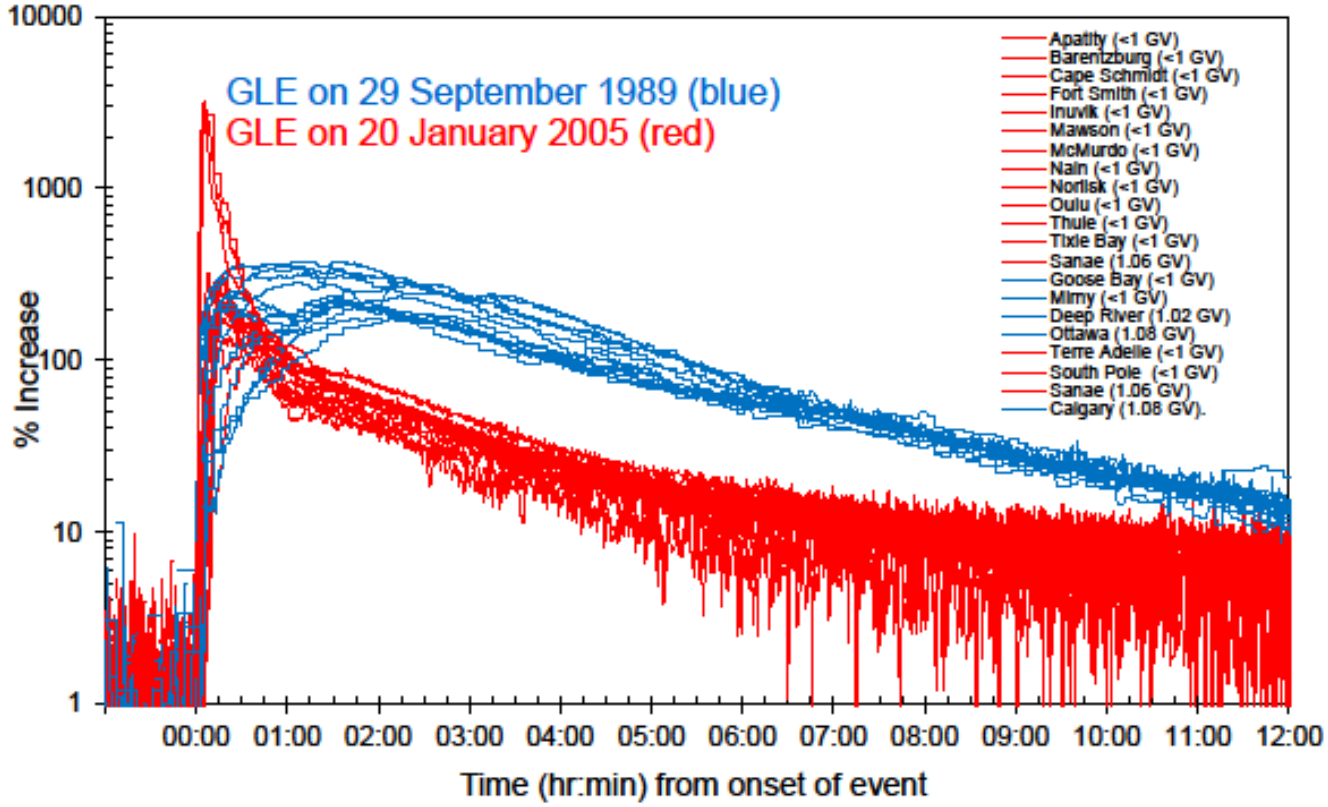
Ground-level Enhancement (GLE) = "cosmic" rays from sun



Ground-level ~~Enhancement~~ Excitement (GLE)



Two real big ones



Why?

- Because it is there…… (academic)
- Appropriate Science and Technology
- Contribution to climate change
- Interdisciplinary (M.Sc. and M.Eng.)

Academic (theory)

Three forms of the Transport Equation

$$\frac{\partial U}{\partial t} + \nabla \bullet (\mathbf{V}U - \mathbf{K} \bullet \nabla U) - \frac{1}{3}(\nabla \bullet \mathbf{V})\frac{\partial}{\partial p}(pU) = 0$$

or, in terms of f

$$\frac{\partial f}{\partial t} + \nabla \bullet (\mathbf{V}f - \mathbf{K} \bullet \nabla f) - \frac{1}{3p^2}(\nabla \bullet \mathbf{V})\frac{\partial}{\partial p}(p^3 f) = 0$$

or, slightly manipulated

$$\frac{\partial f}{\partial t} + \mathbf{V} \bullet \nabla f - \nabla \bullet (\mathbf{K} \bullet \nabla f) - \frac{1}{3p^2}(\nabla \bullet \mathbf{V})\frac{\partial f}{\partial \ln p} = 0$$

Poster
Godfrey Mosotho

Not changed for 45 years

Too difficult to solve analytically …..

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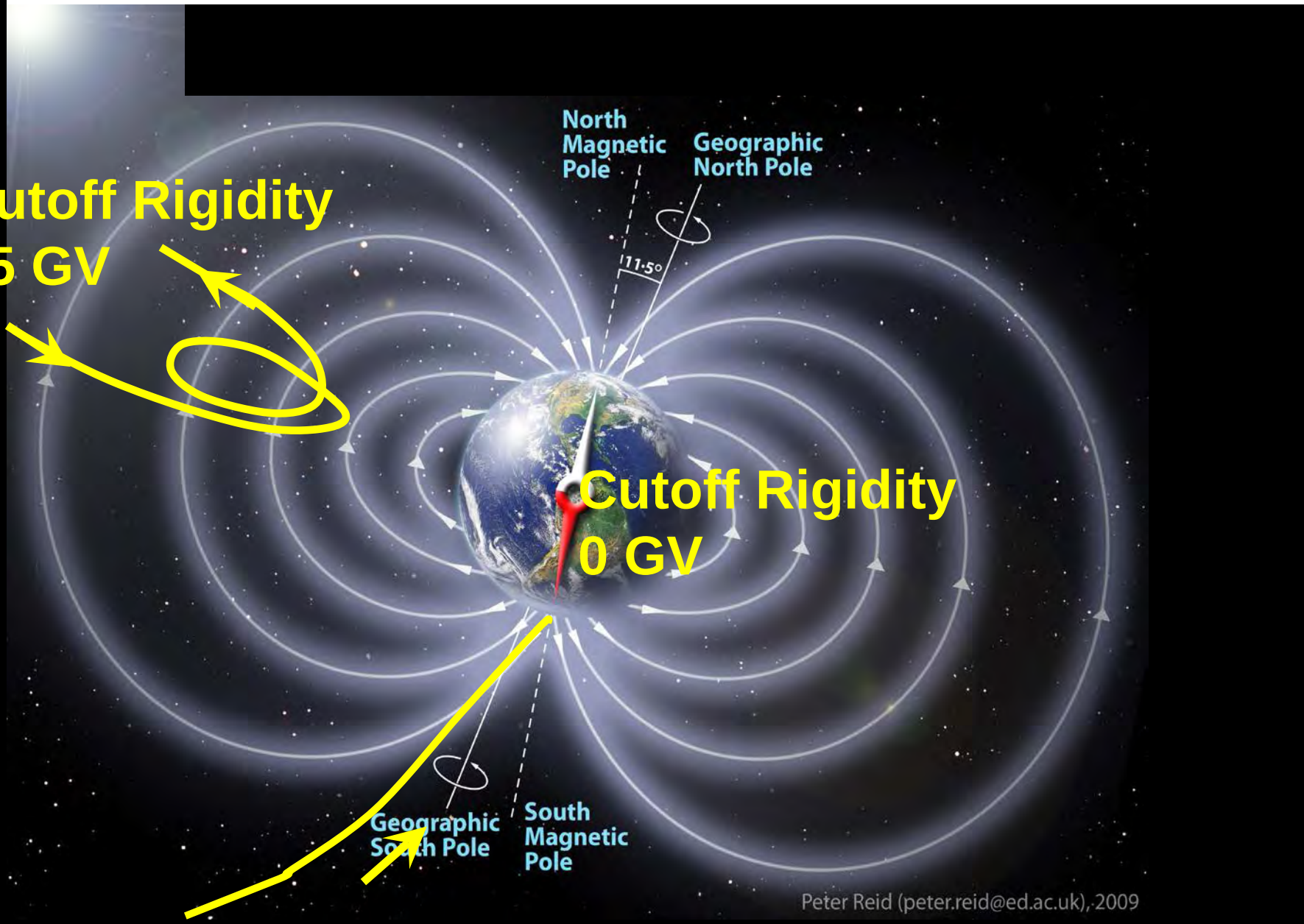
Pre-2006 SANAP Mission

To increase understanding of the natural environment and life in the Antarctic and Southern Ocean through appropriate science and technology

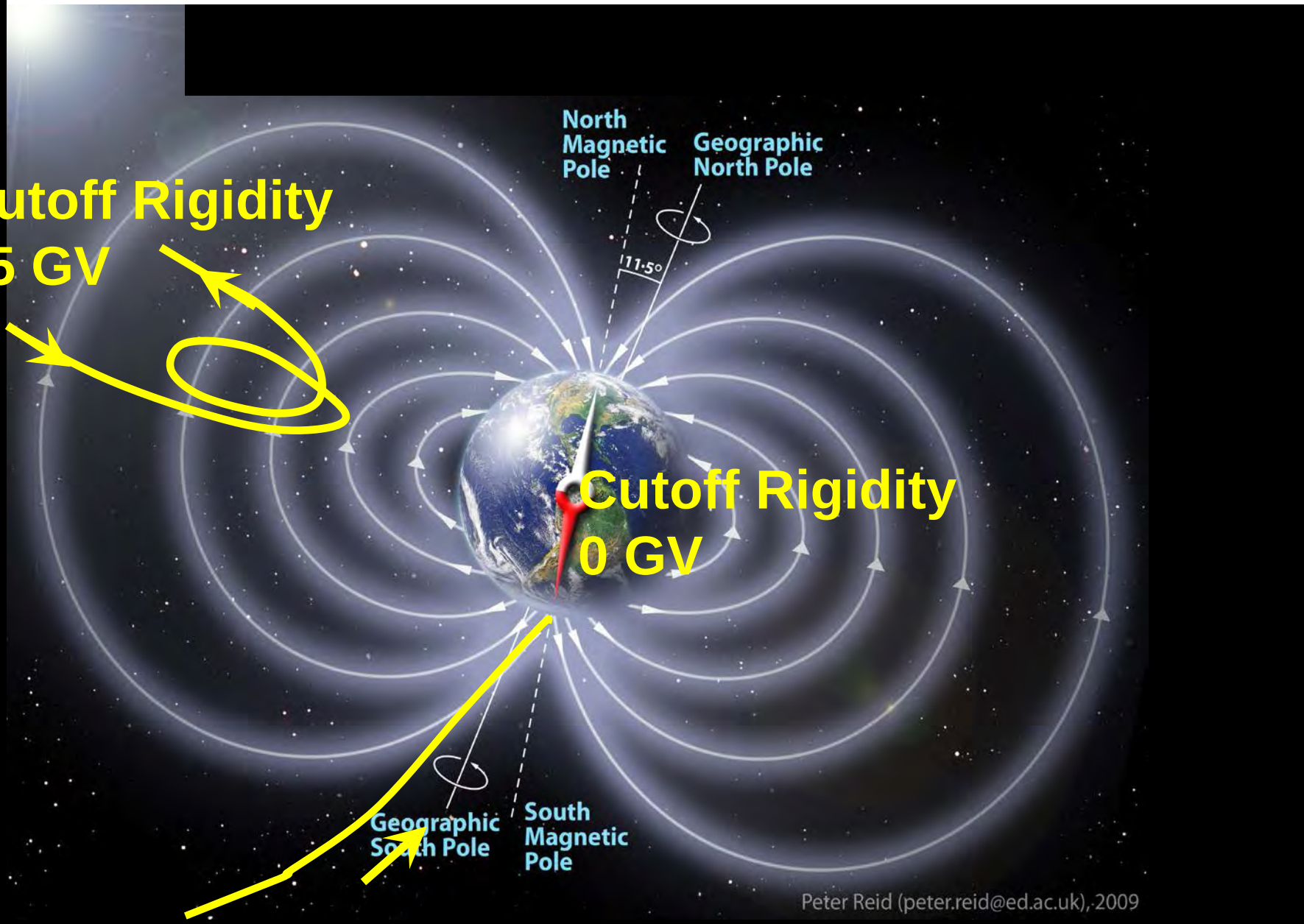
Pre-2006 SANAP Mission

To increase understanding of the natural environment and life in the Antarctic and Southern Ocean through APPROPRIATE science and technology

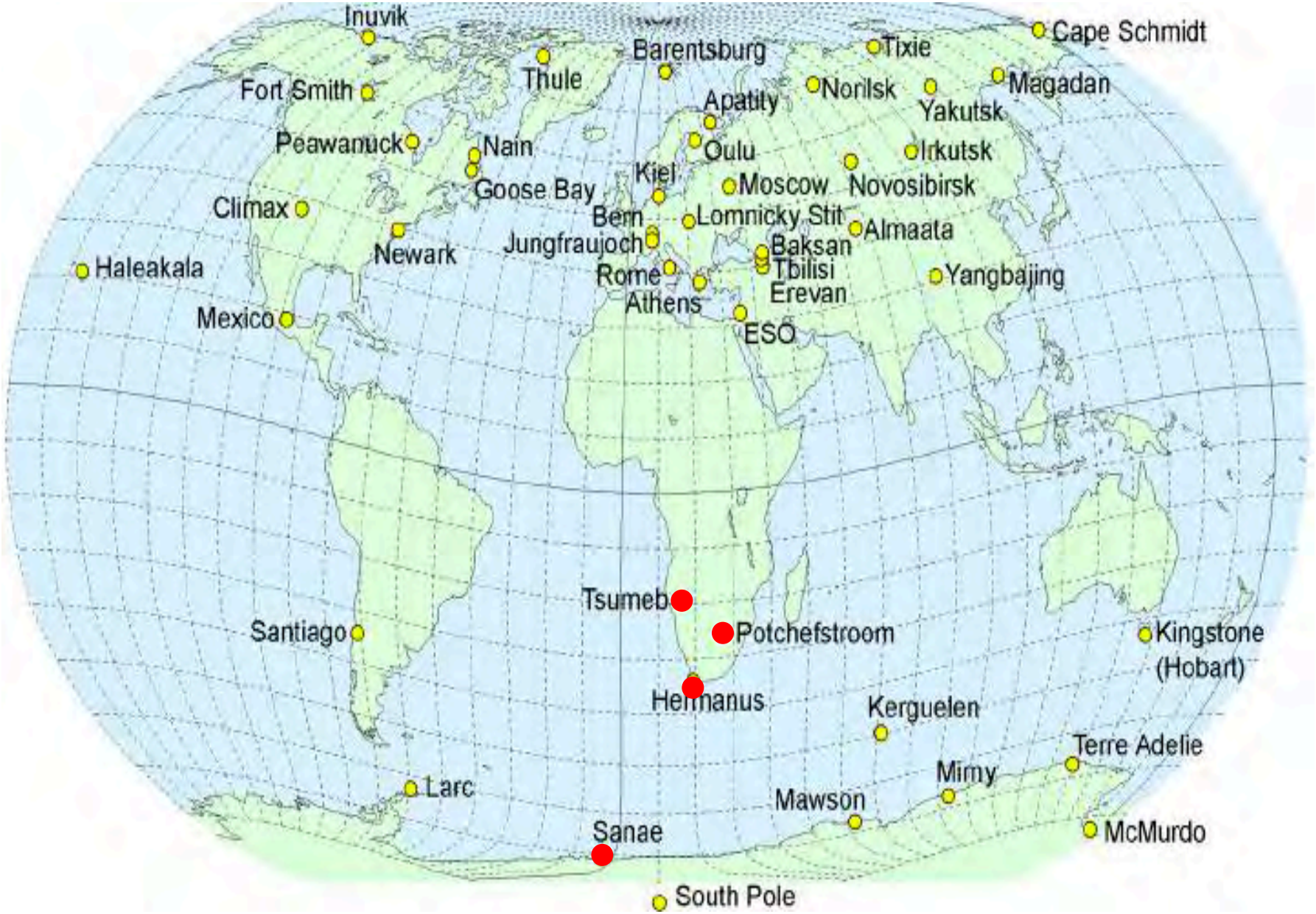
The poles are better



The poles are better – a window into geospace



Appropriate…….



Appropriate…….

- One space mission > $ 70 M = R 700 M

- Neutron monitors = R 250 K per year x 40 NMs

  x 60 years = R 600 M

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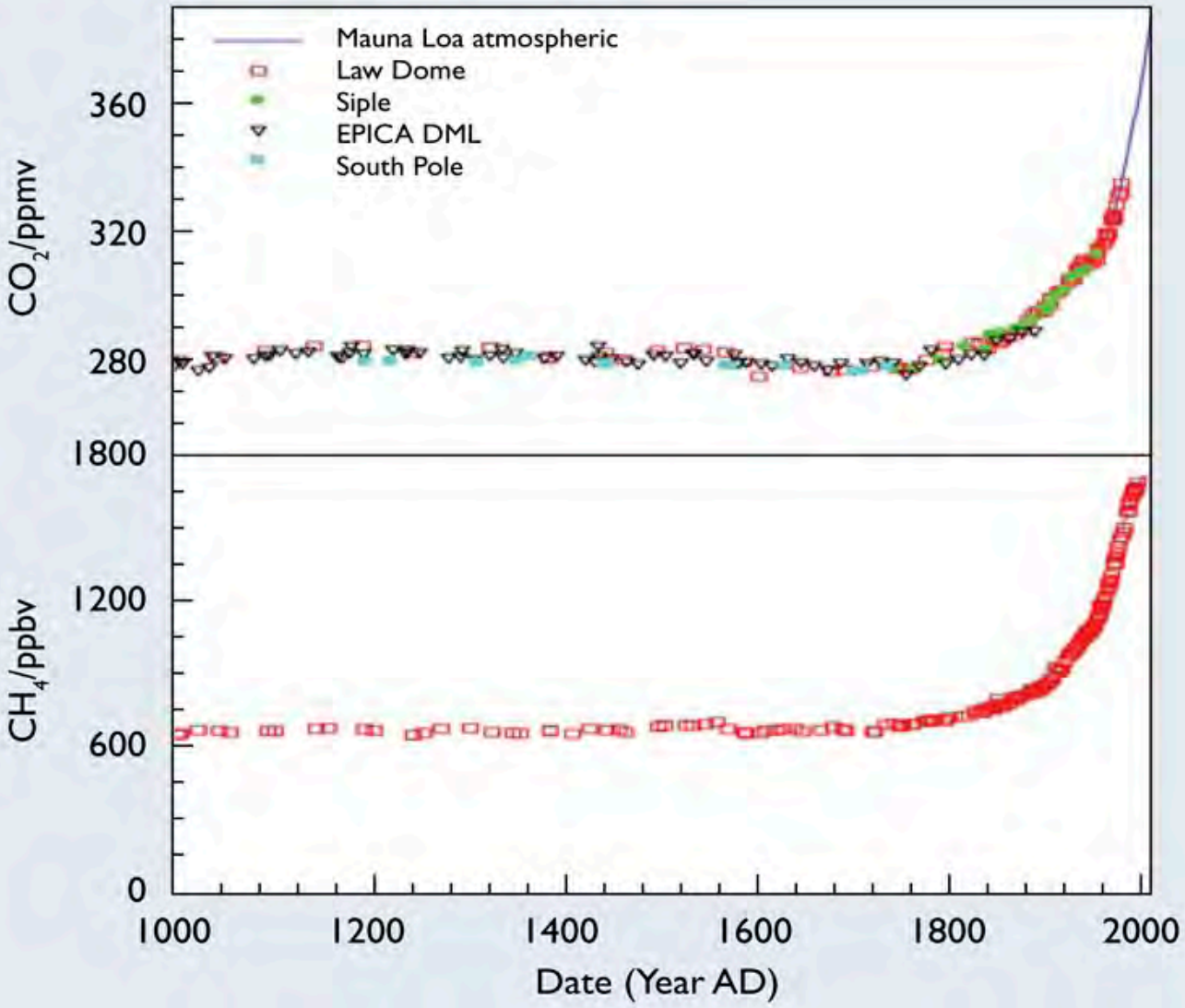
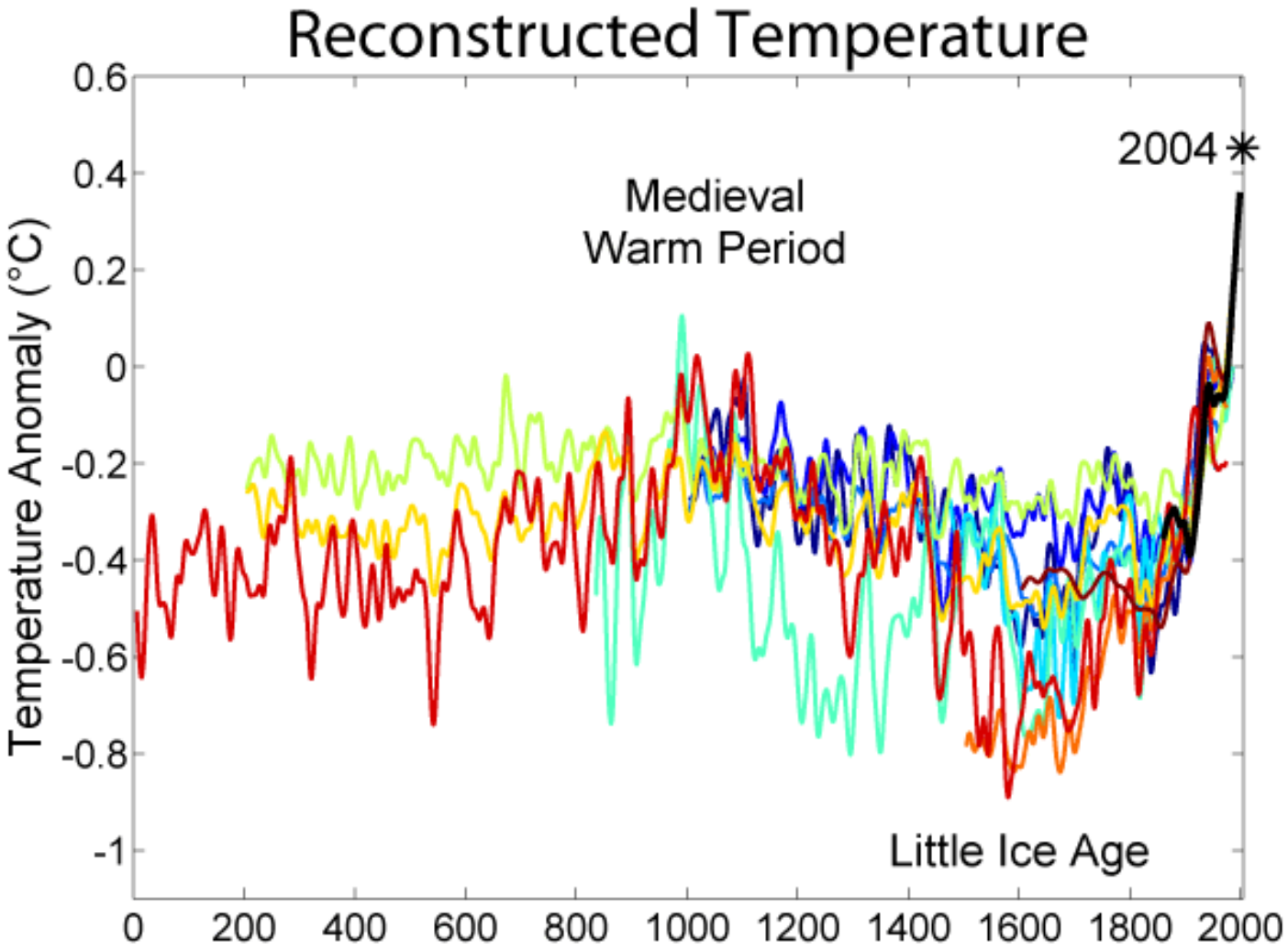
Climate change

Fig. 2: CO_2 and CH_4 over the last 1,000 years[1-4]



Climate change



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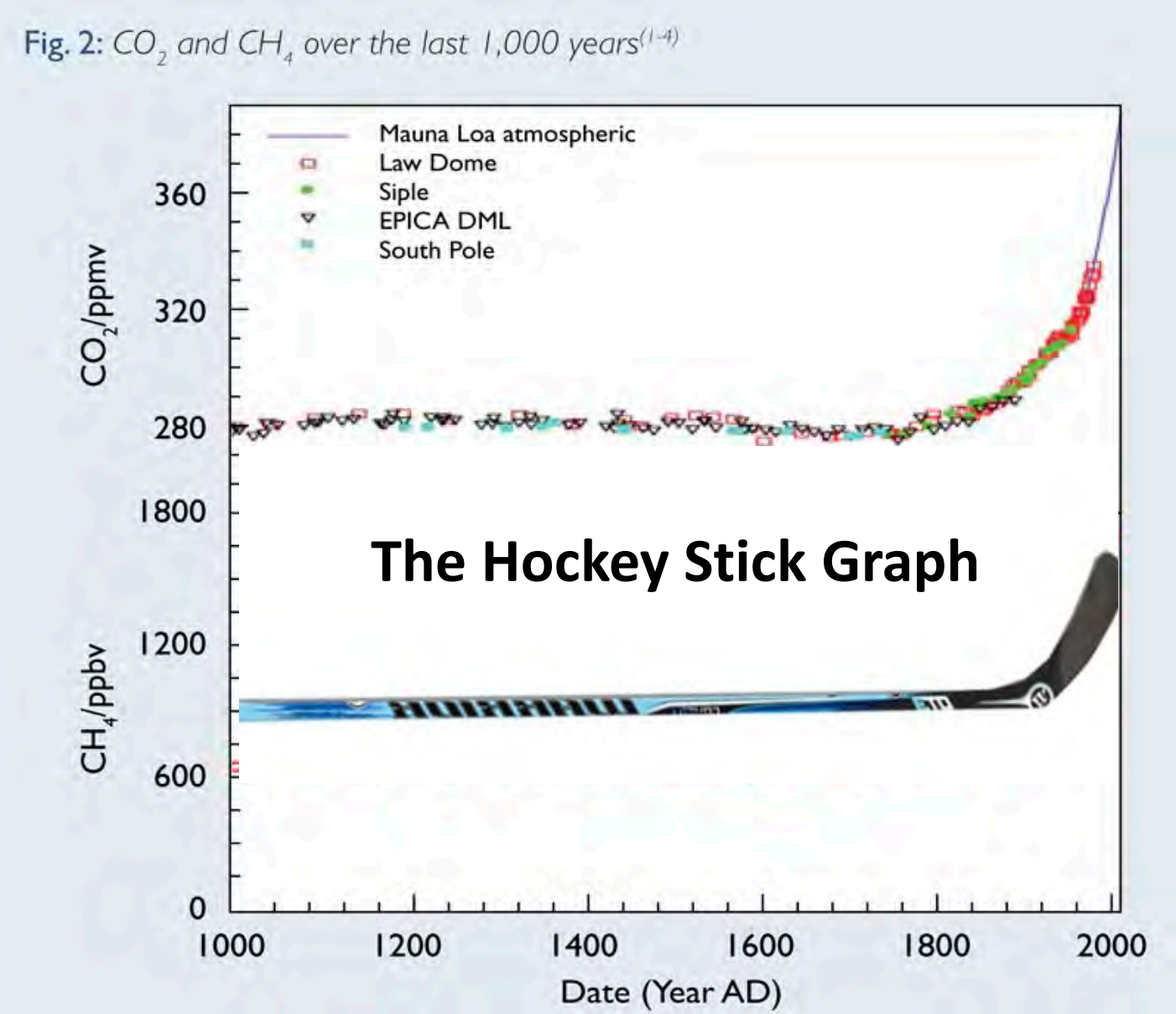
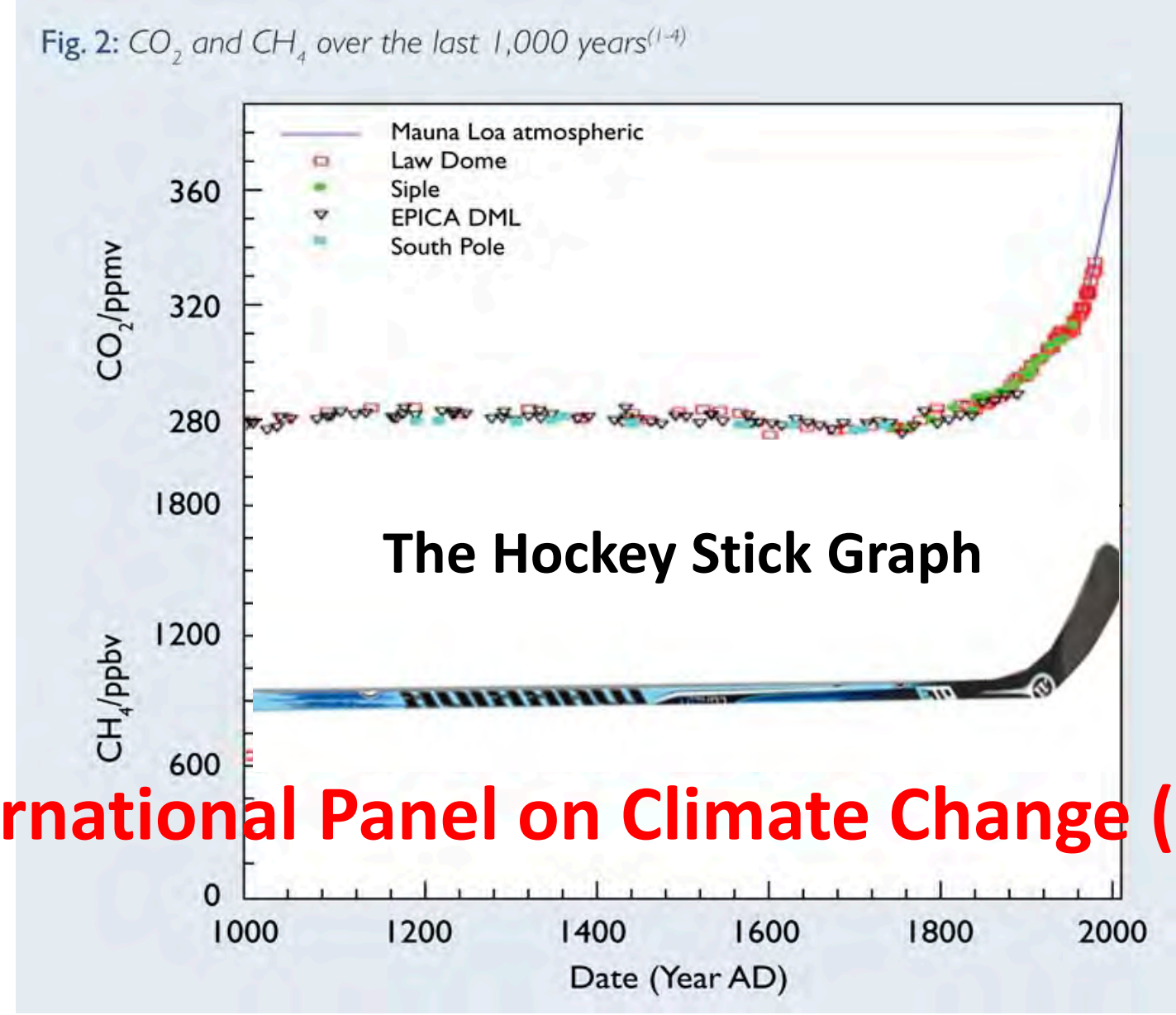


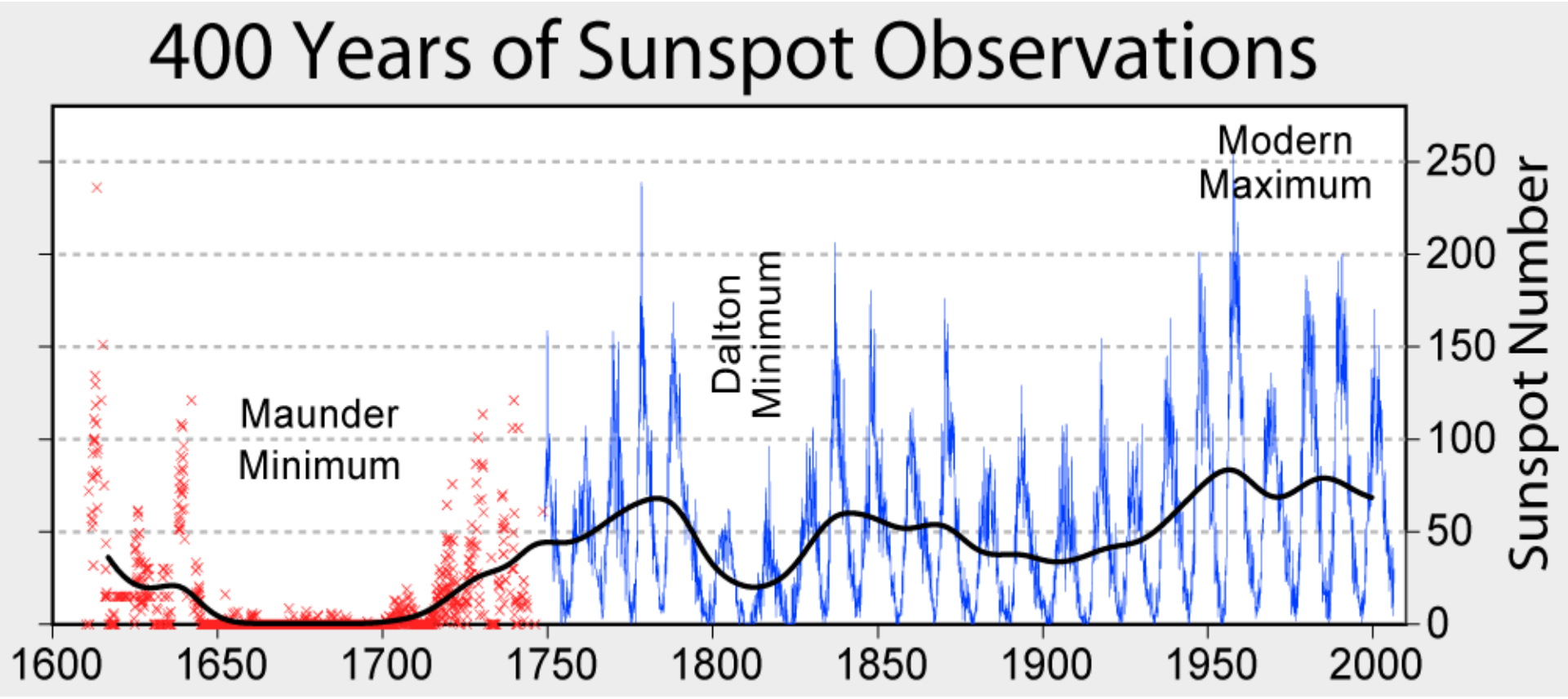
Climate change



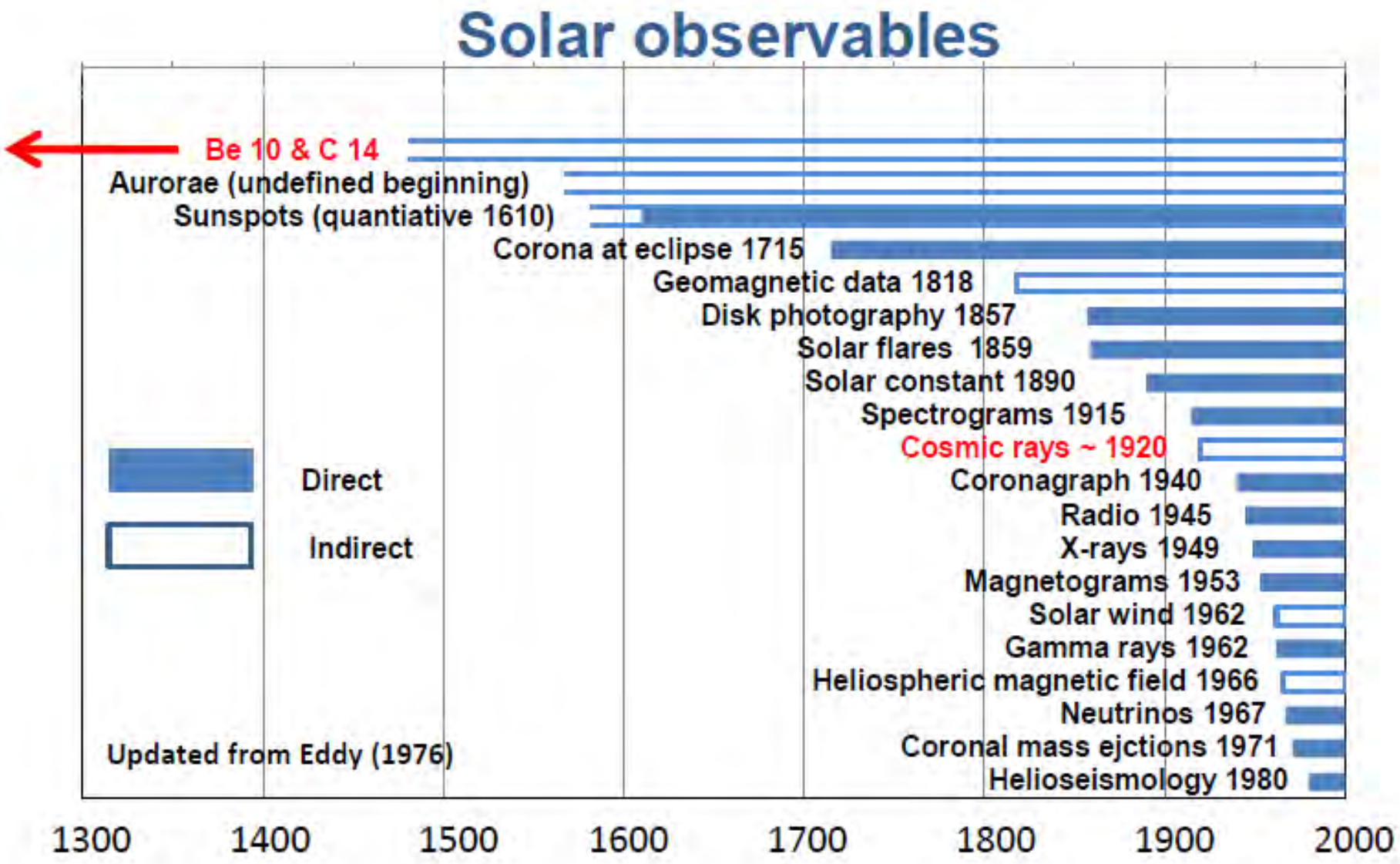
The Hockey Stick Graph

International Panel on Climate Change (IPCC)

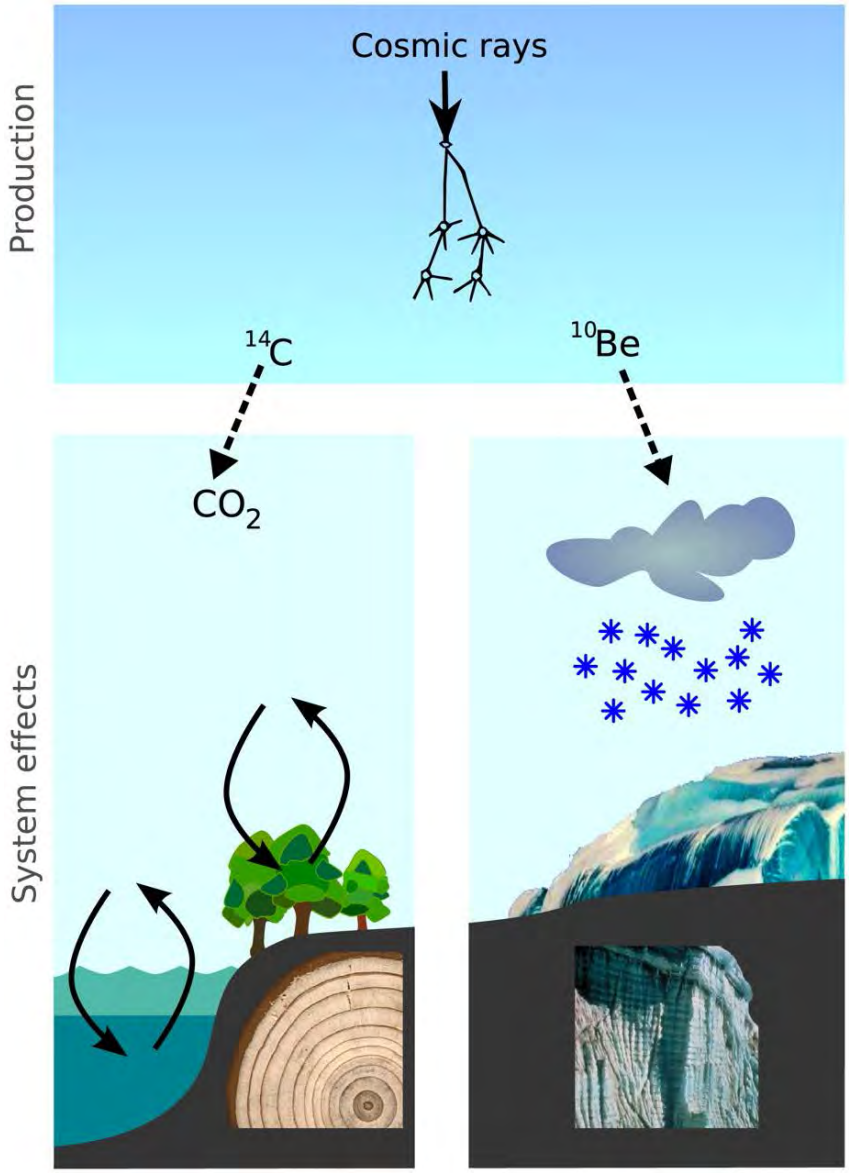
Climate change



History of the Sun

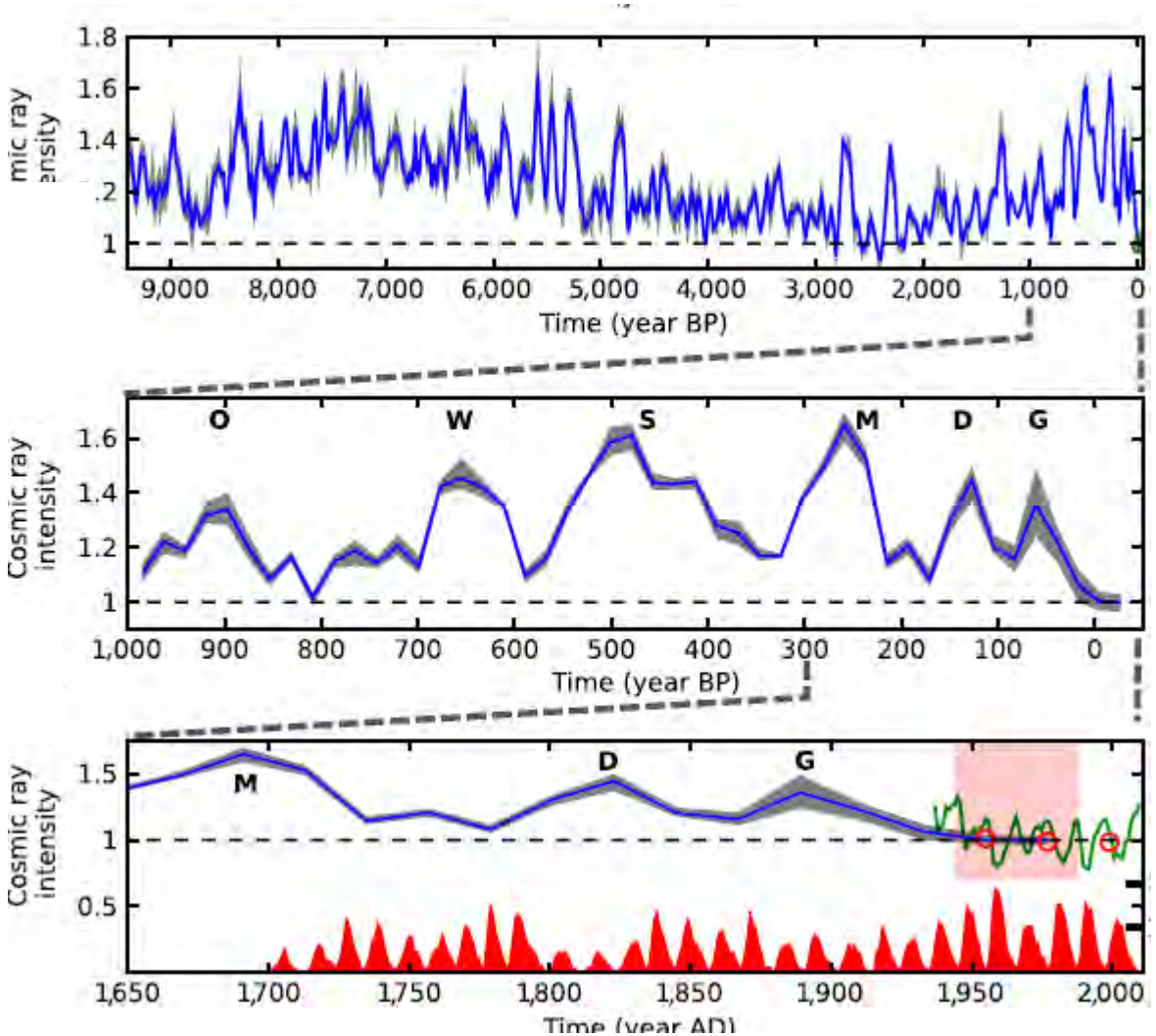


Paleo-cosmic rays: ^{14}C and ^{10}Be



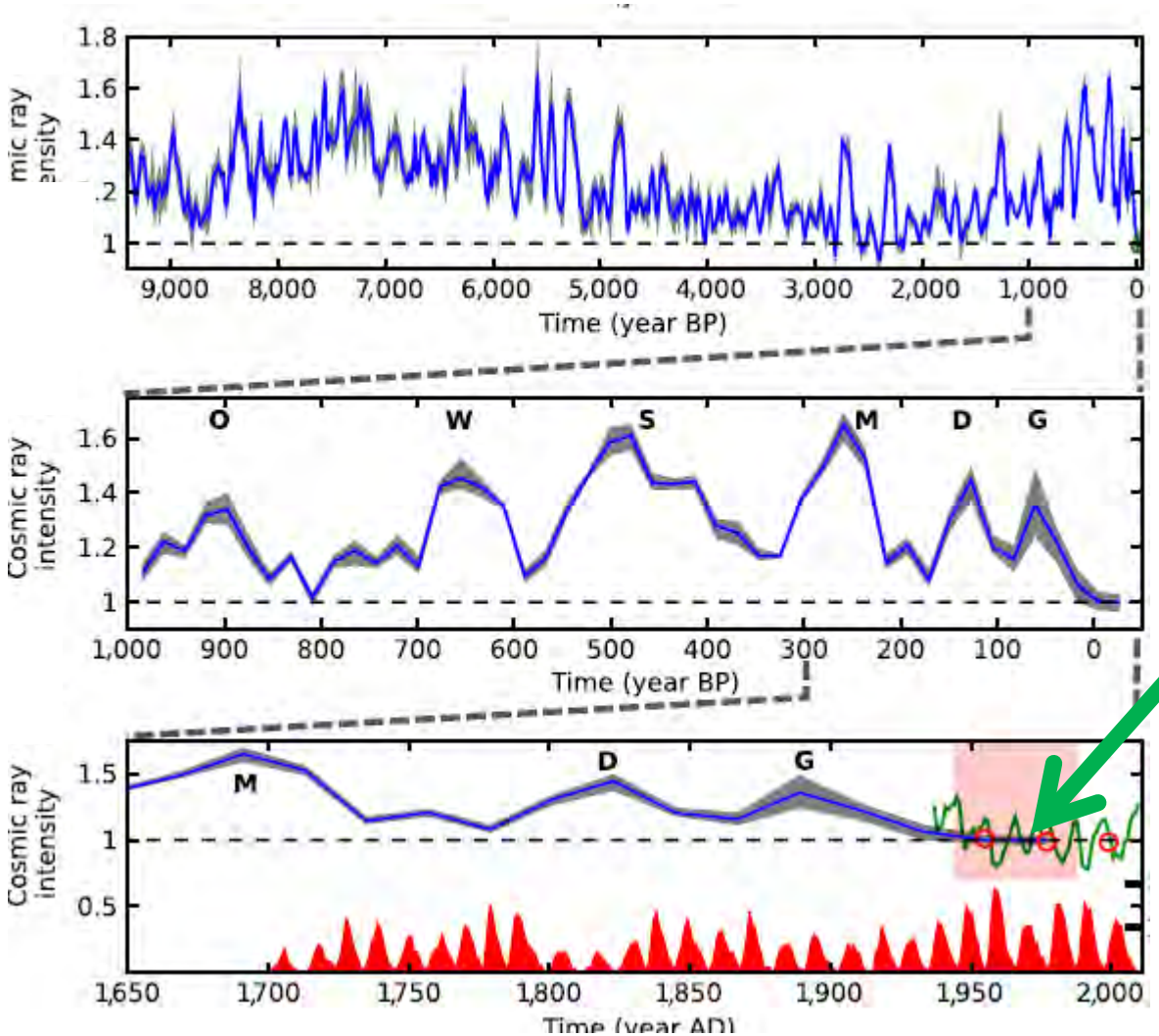
Paleo-cosmic rays: ^{10}Be

^{10}Be in polar ice … Earth's neutron monitor



Steinhilber et al. (2012)

^{10}Be in polar ice … Earth's neutron monitor



Real neutron monitor

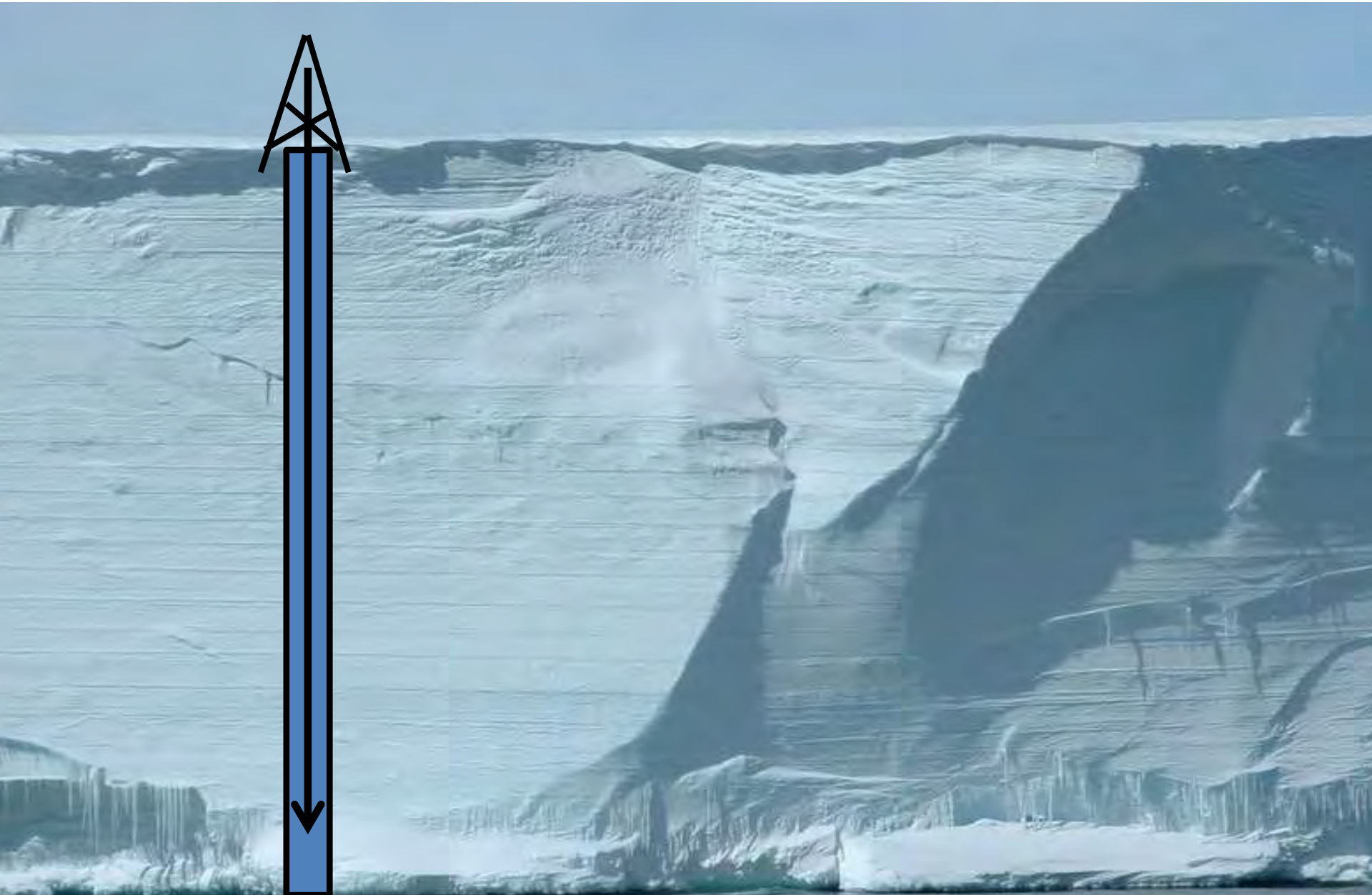
Steinhilber et al. (2012)

Ice shelf in Queen Maud Land

Ice shelf in Queen Maud Land

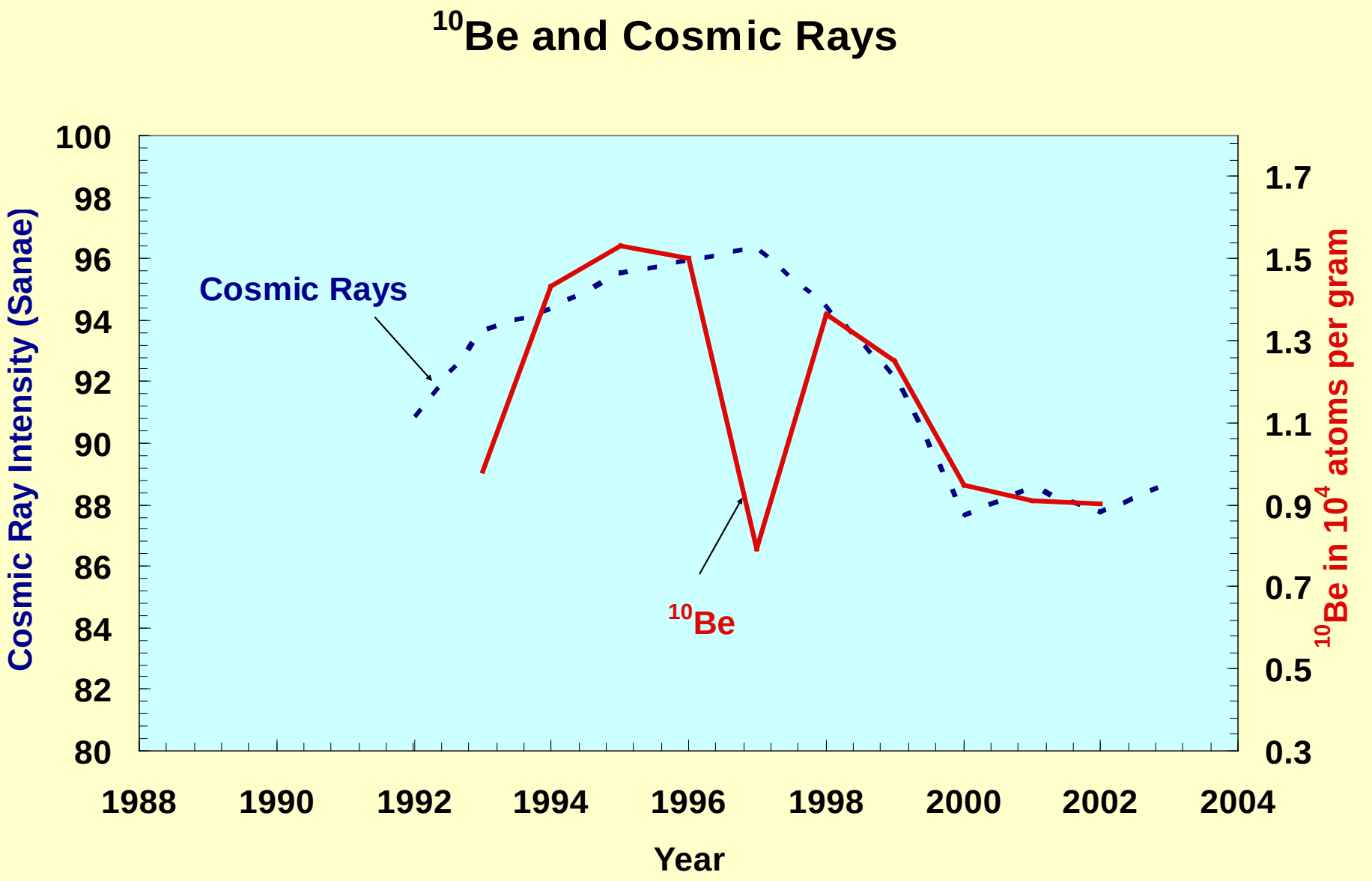
Ice shelf in Queen Maud Land

Shallow drilling ……. 60 years deep



Pilot Project 2006

Pilot project 2006



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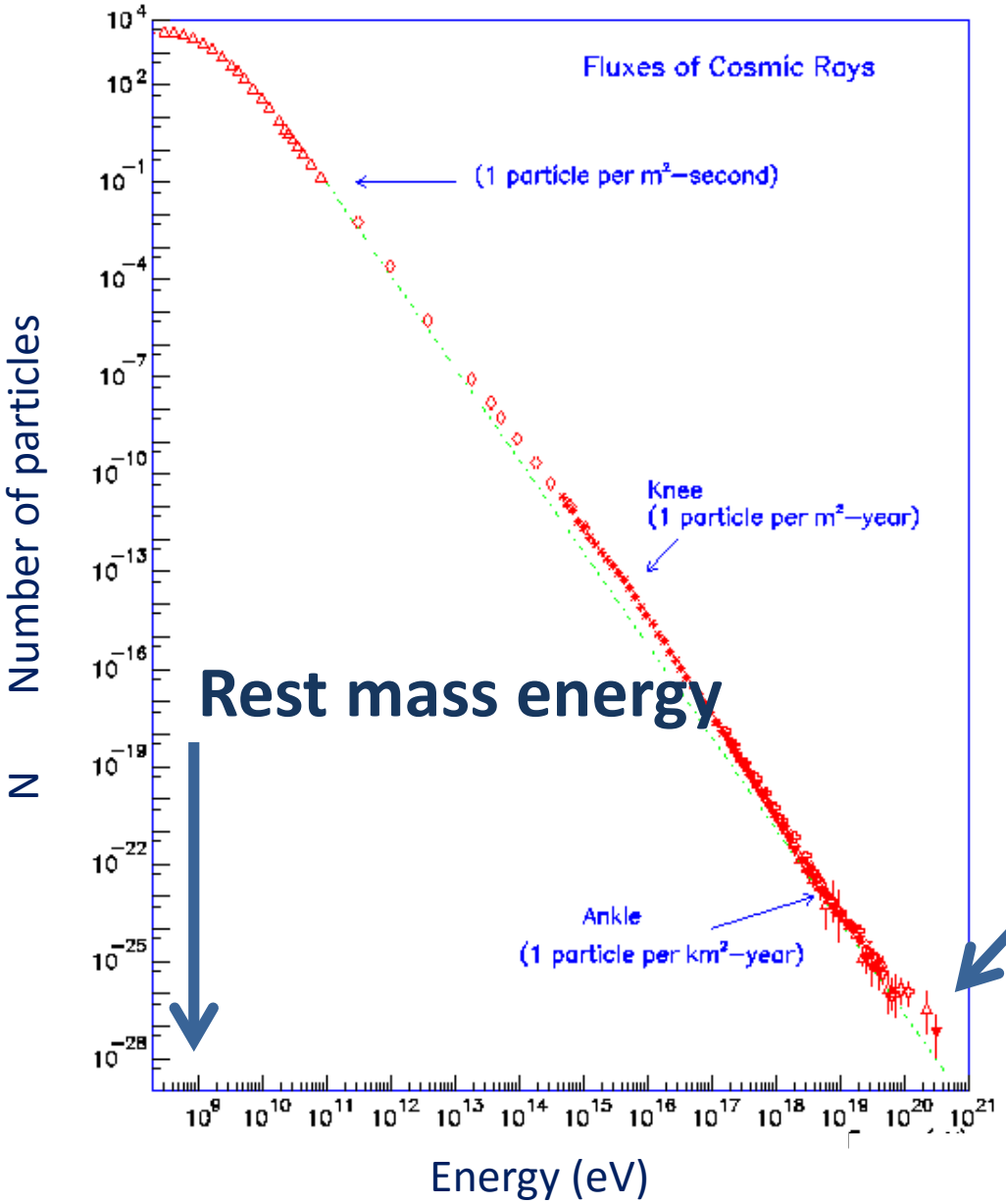
Thank you:

NRF/DST
DEA
Rhodes University Organisers

Cosmic-ray spectrum



Rest mass energy

Cricket Ball