Neutron Monitors—the Original Space Weather Instrument

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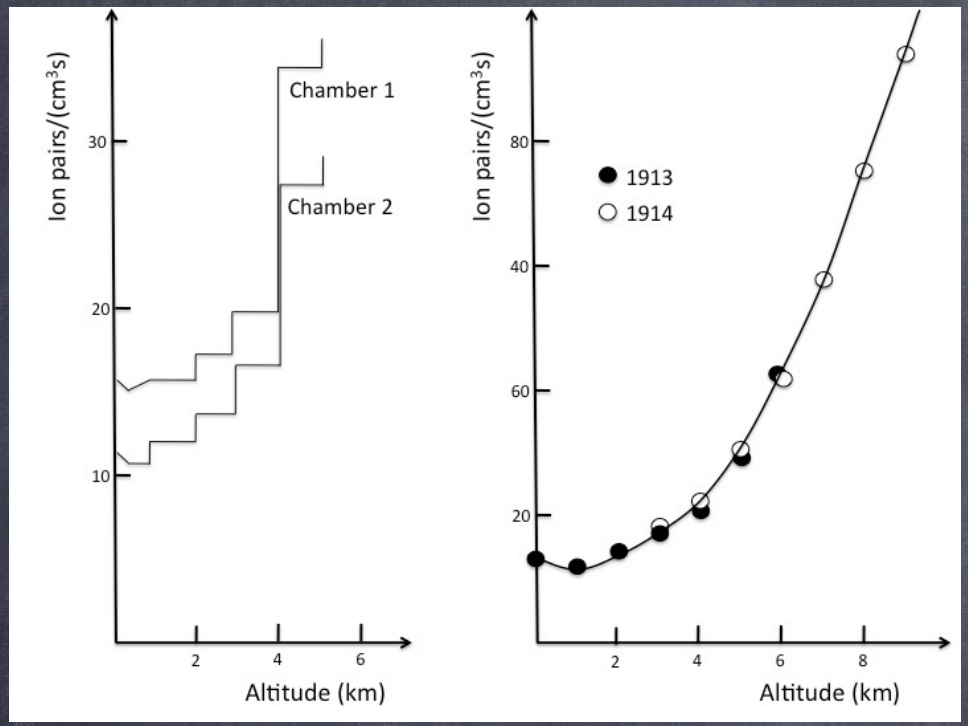
University of New Hampshire

Neutron Monitors

- What they are and how they work, individually and collectively
- What they tell us about space weather

Cosmic Rays Go Way Back

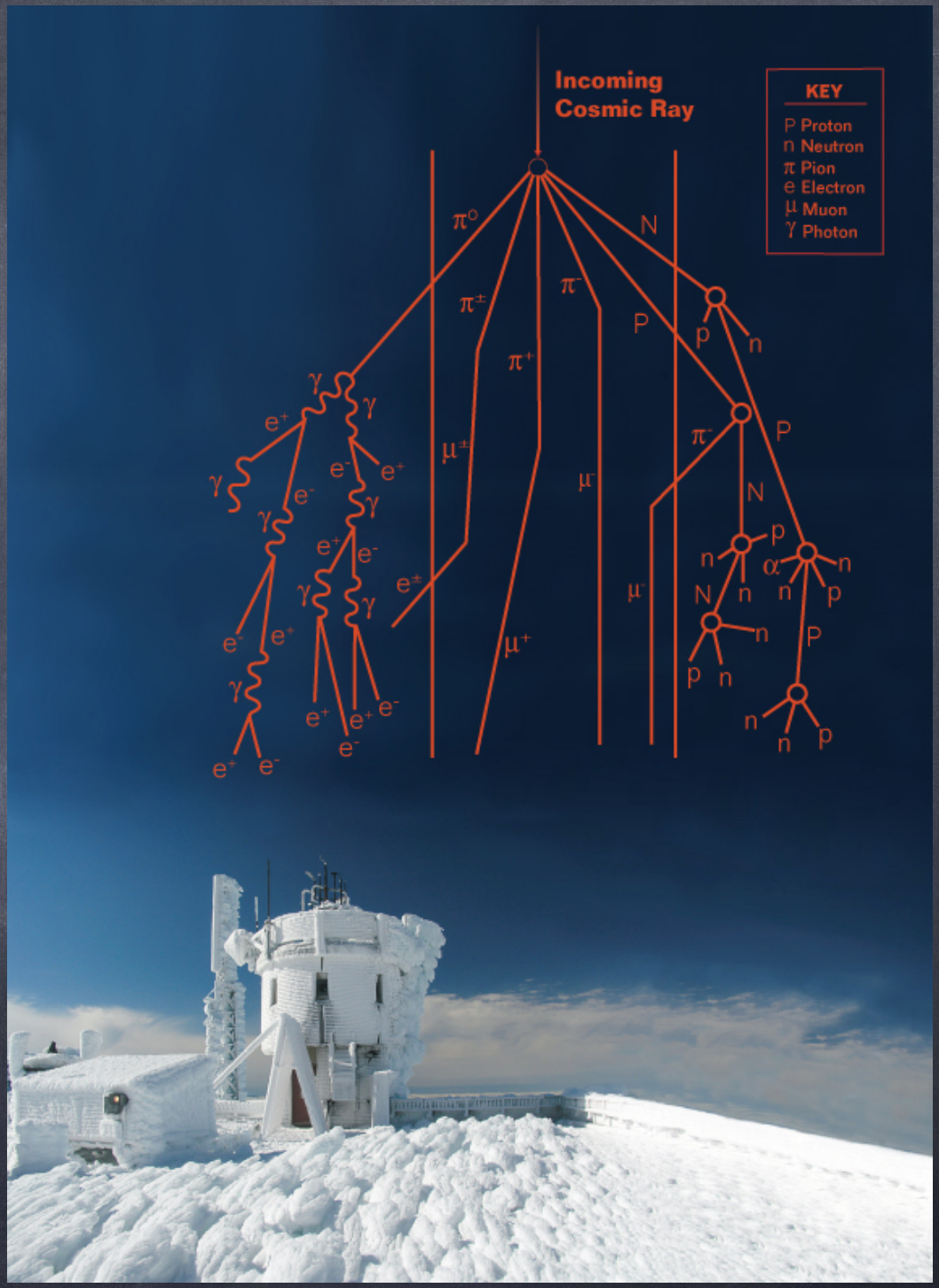


Hess 1912

Kohlhörster 1913, 1914

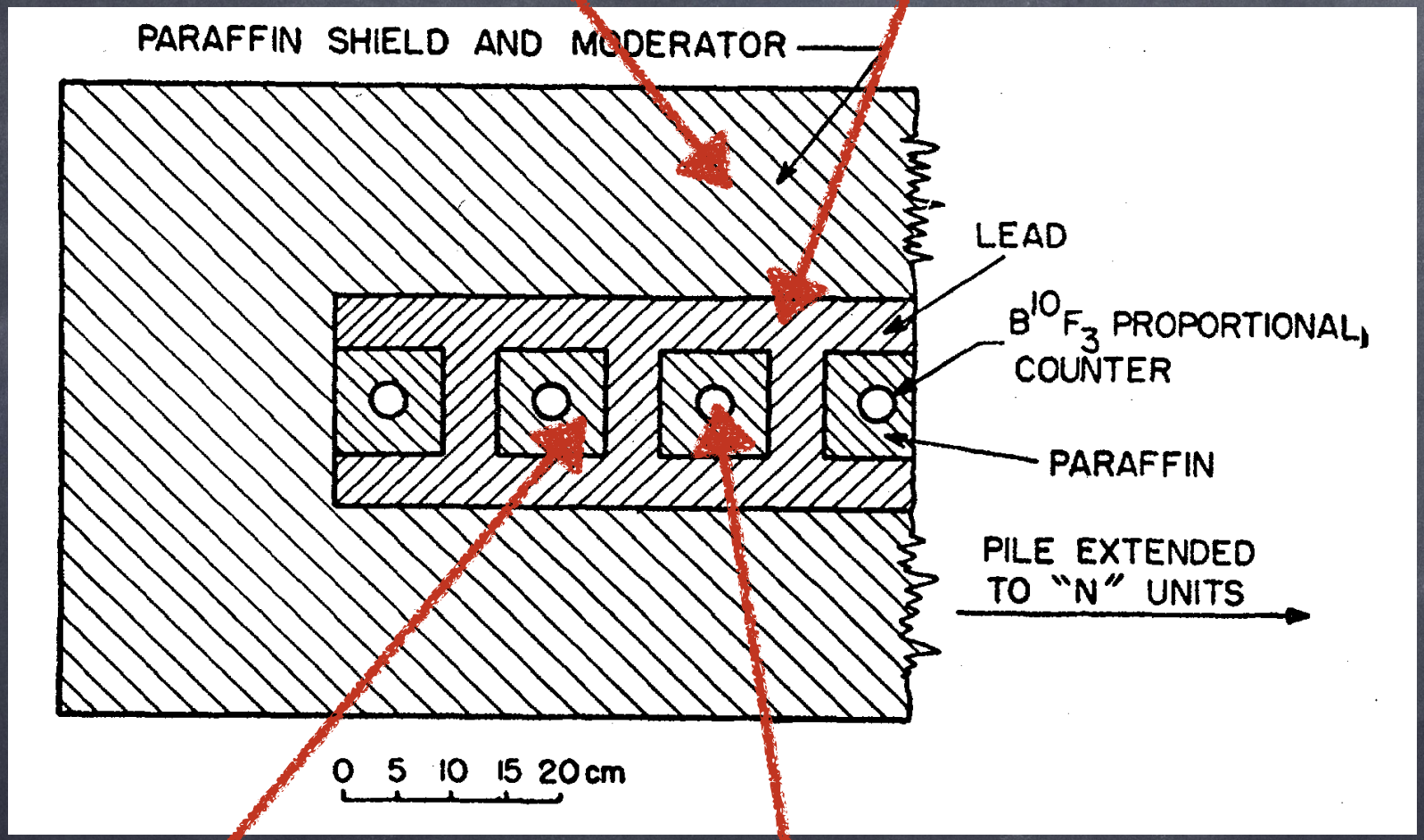
Victor Hess August 1912

Cosmic rays produce neutrons at ground level if the energy is sufficient, i.e., >500 MeV).



Reflects and absorbs low-E neutrons

Lead Multiplier



Moderator

Absorber/Counter

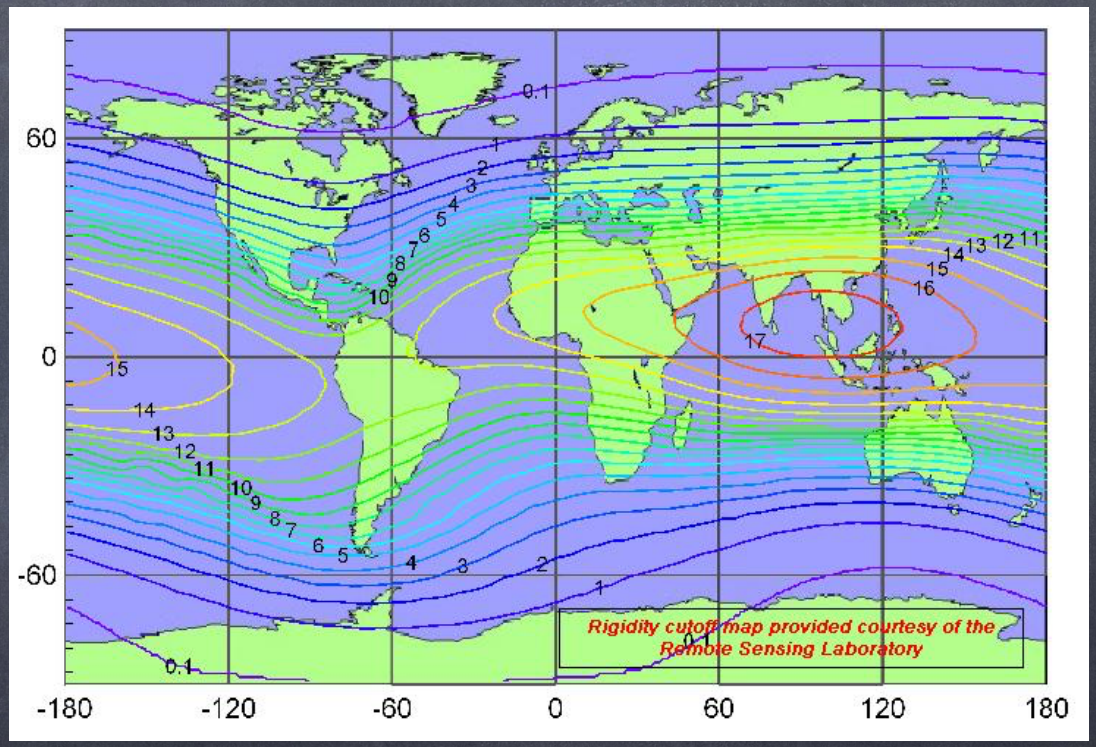
Original Simpson (1953) design

Different stations measure different things, mostly due to the local threshold and altitude.

Particles are sorted by "rigidity"

$R\ (V) = pc/Ze.$

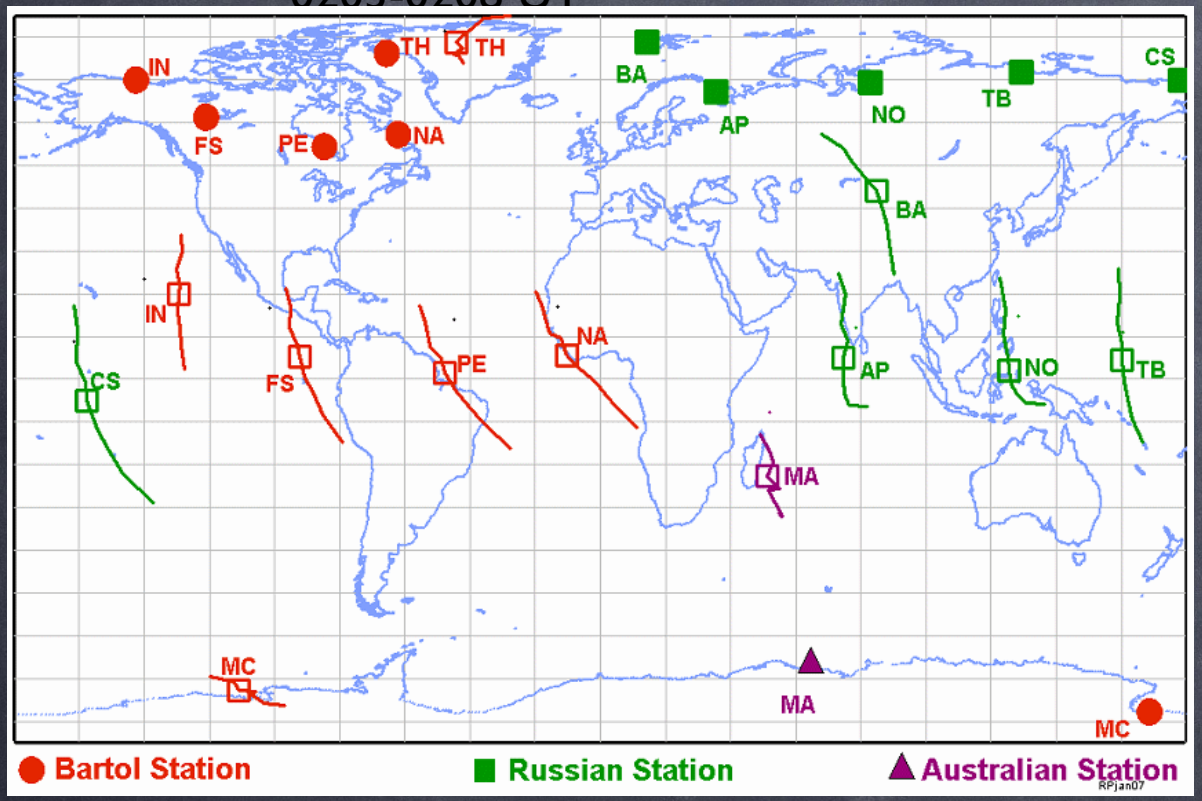
$r_{Larmor} \propto R.$

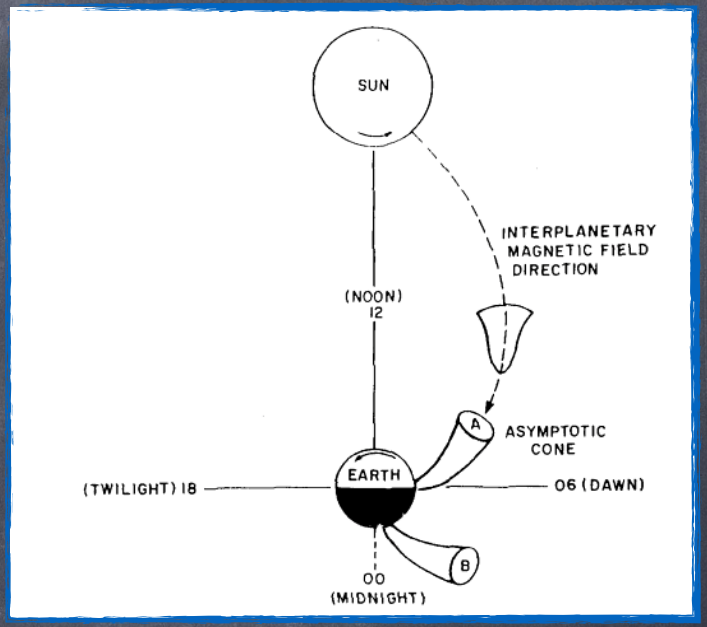


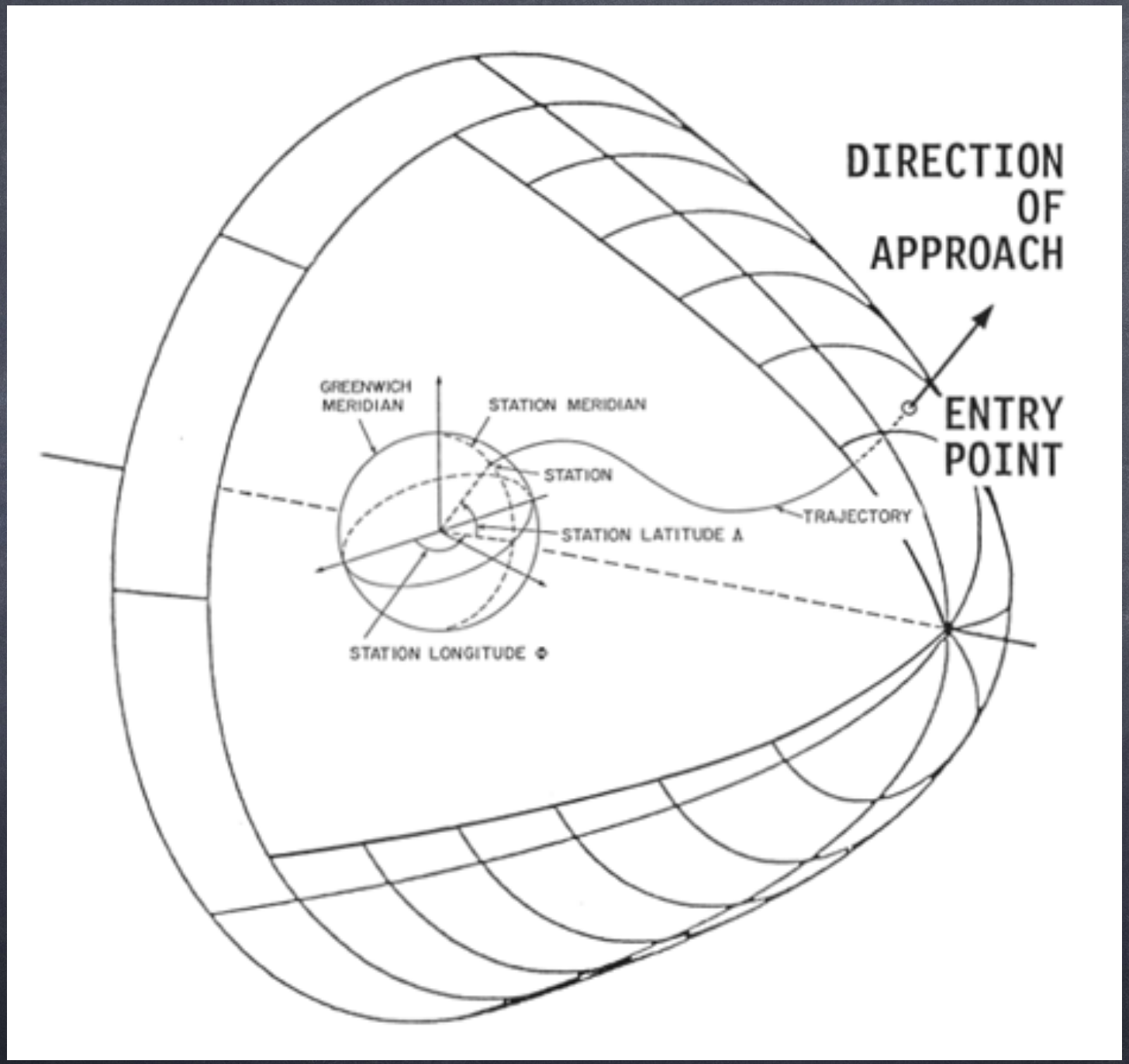
Another effects contribute—how beamed are the particles and can they penetrate the atmosphere?

So-called Asymptotic Directions

0203-0208 UT

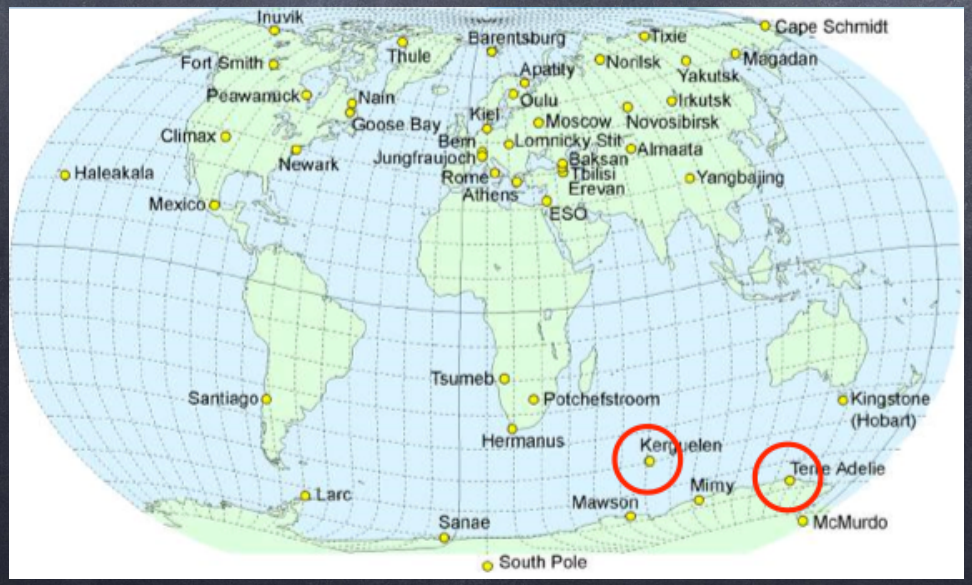




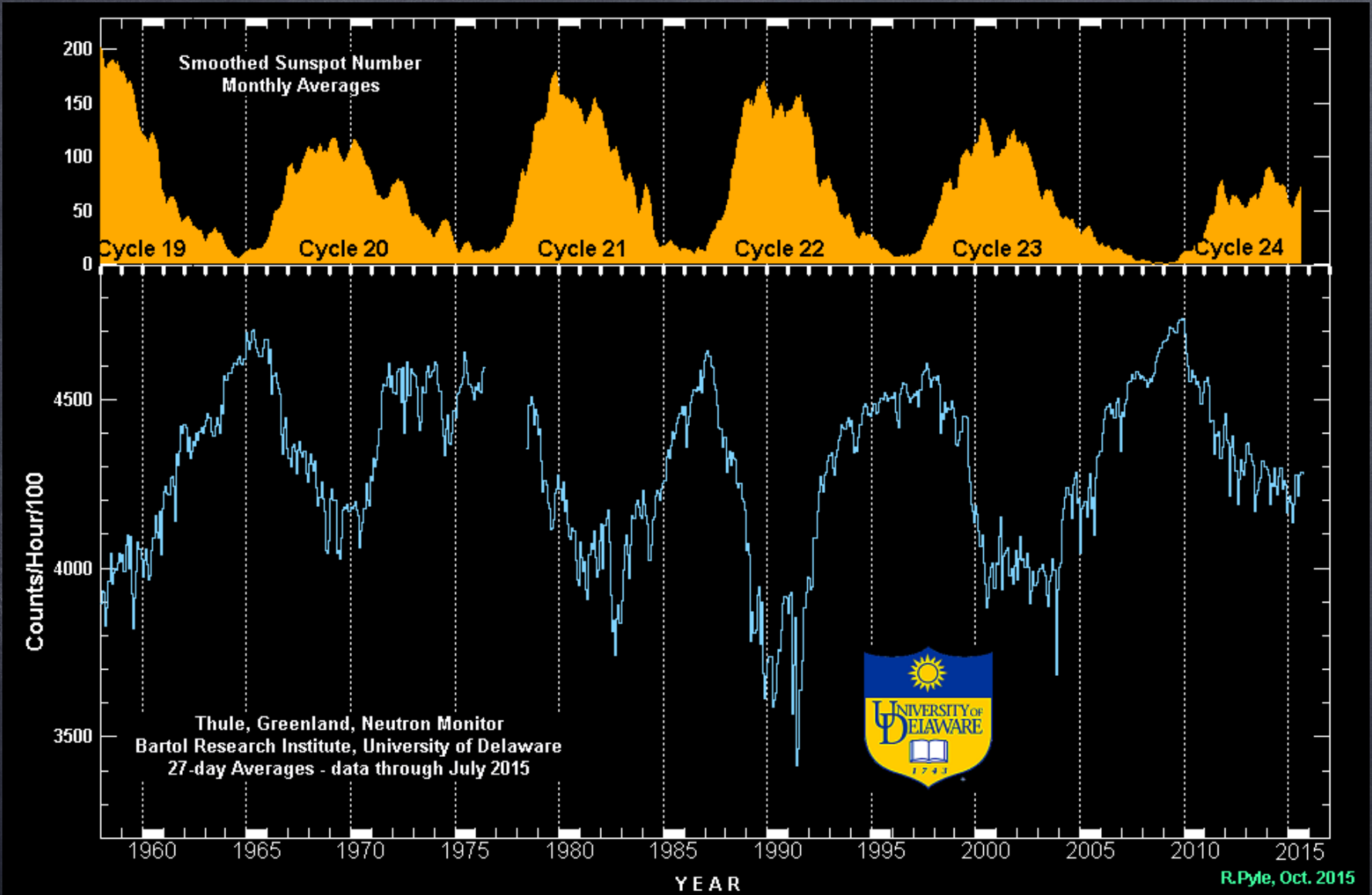

DIRECTION
OF
APPROACH
ENTRY
POINT
GREENWICH
MERIDIAN
STATION MERIDIAN
STATION
TRAJECTORY
STATION LATITUDE λ
STATION LONGITUDE Φ

International Geophysical Year 1957–1958

- Space Age Started
  - Sputnik, Explorer
  - Discovery of radiation belts
- Studies of cosmic rays with NM network



Long term space weather



Solar modulation refers to the influence the Sun exerts upon the intensity of galactic cosmic rays. As solar activity rises (top panel), the count rate recorded by a neutron monitor in Thule, Greenland decreases (bottom panel).

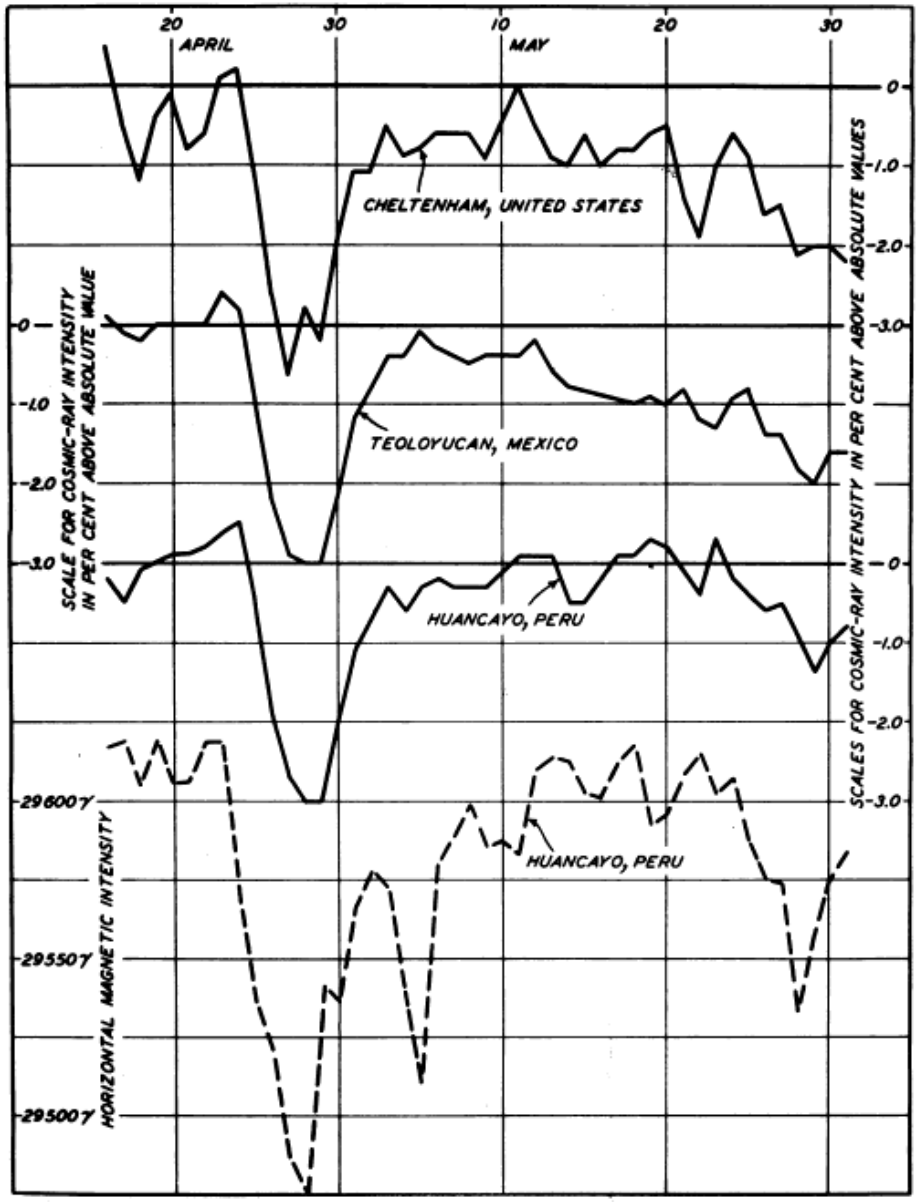


FIG. 1.—Daily means of cosmic-ray intensity and horizontal magnetic intensity, showing effect of magnetic storm of April 25–30, 1937, on cosmic-ray intensity.

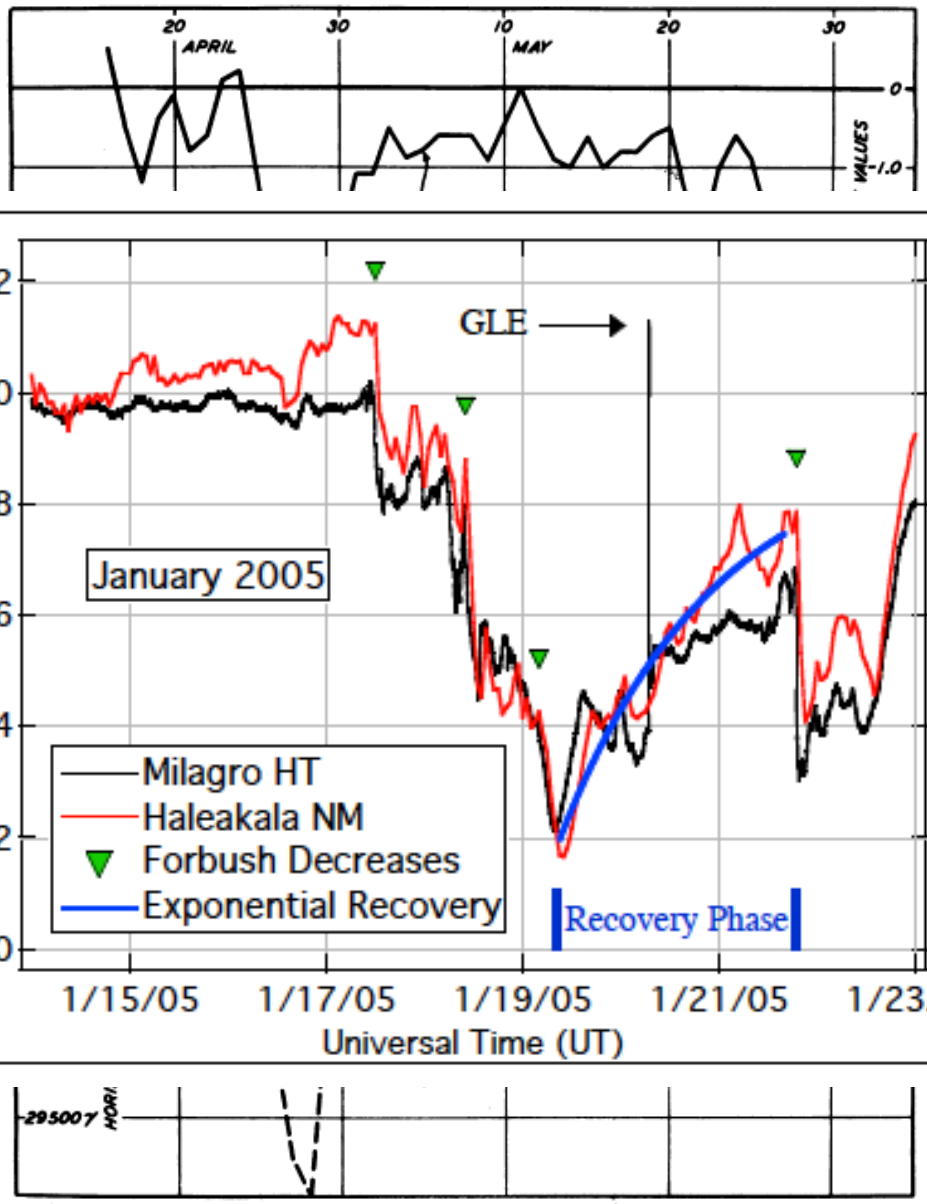
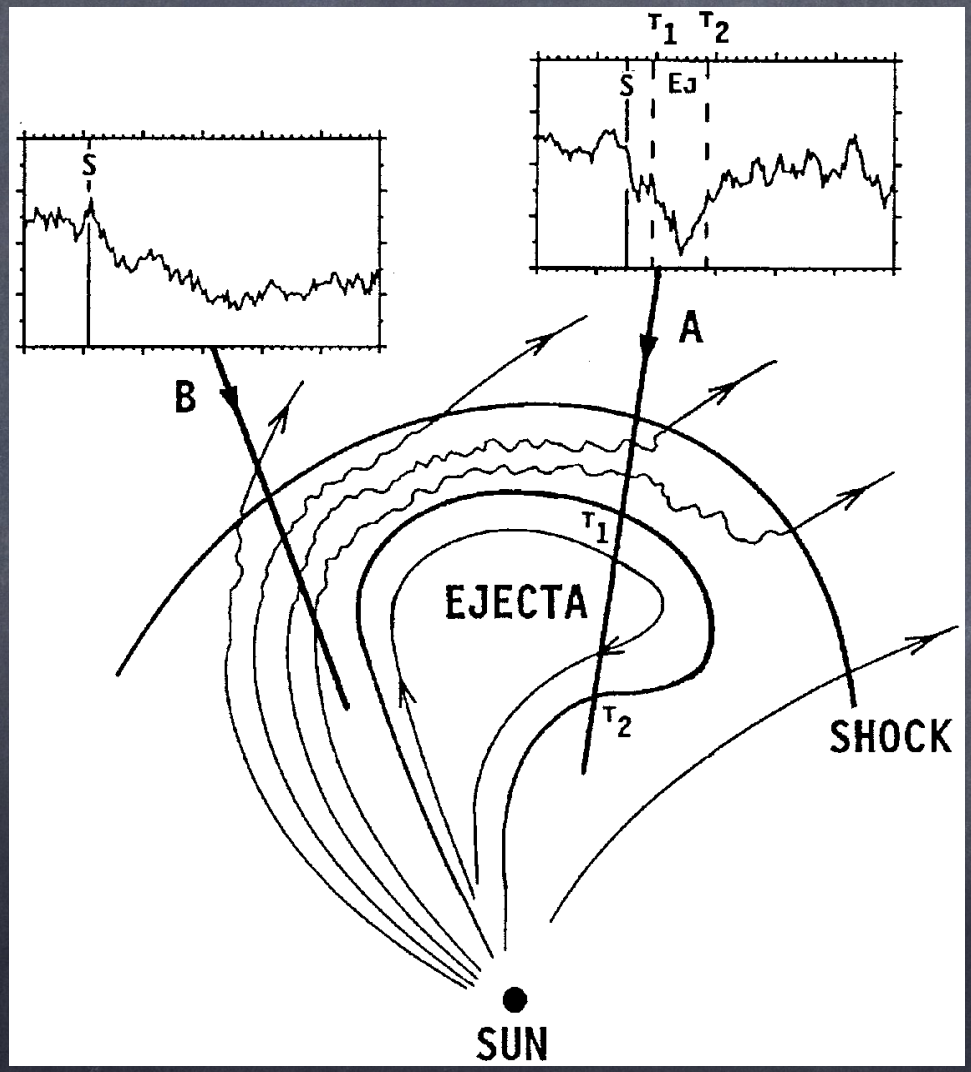


FIG. 1.—Daily means of cosmic-ray intensity and horizontal magnetic intensity, showing effect of magnetic storm of April 25–30, 1937, on cosmic-ray intensity.

Cartoon of NM signal for different CME orientations



Simpson's neutron monitors detected increases as well as decreases, called Ground Level Enhancements.

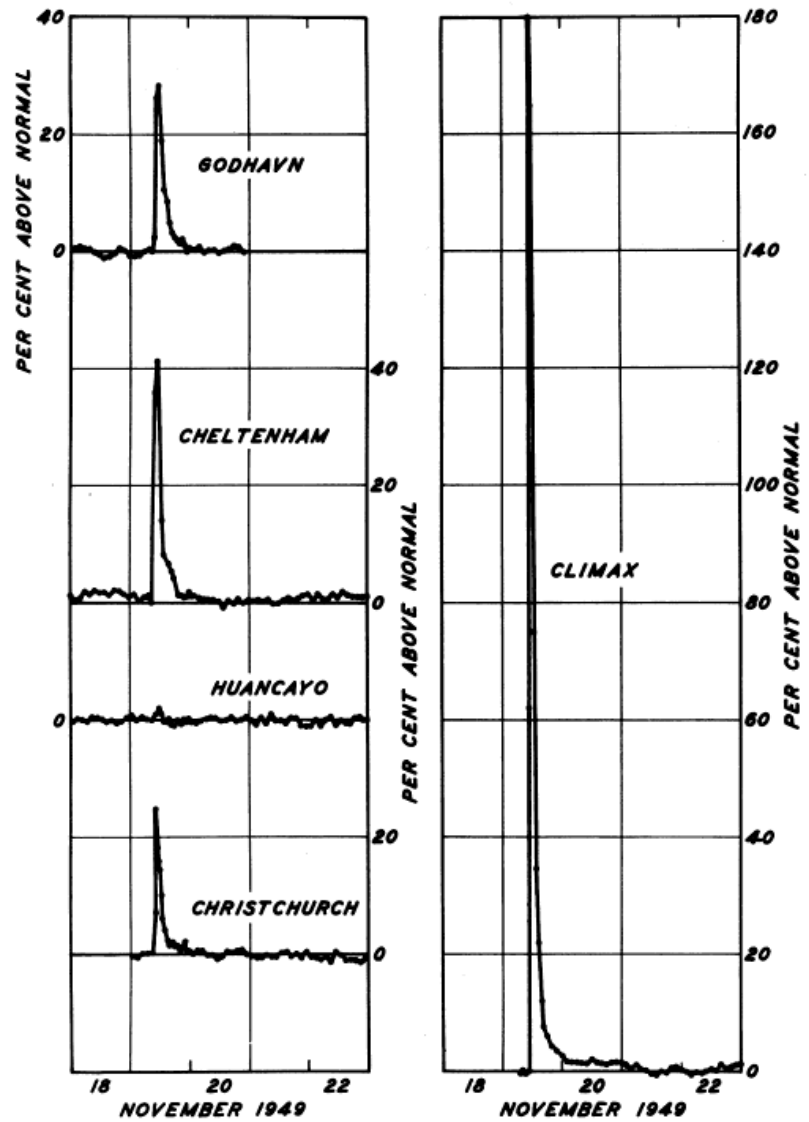
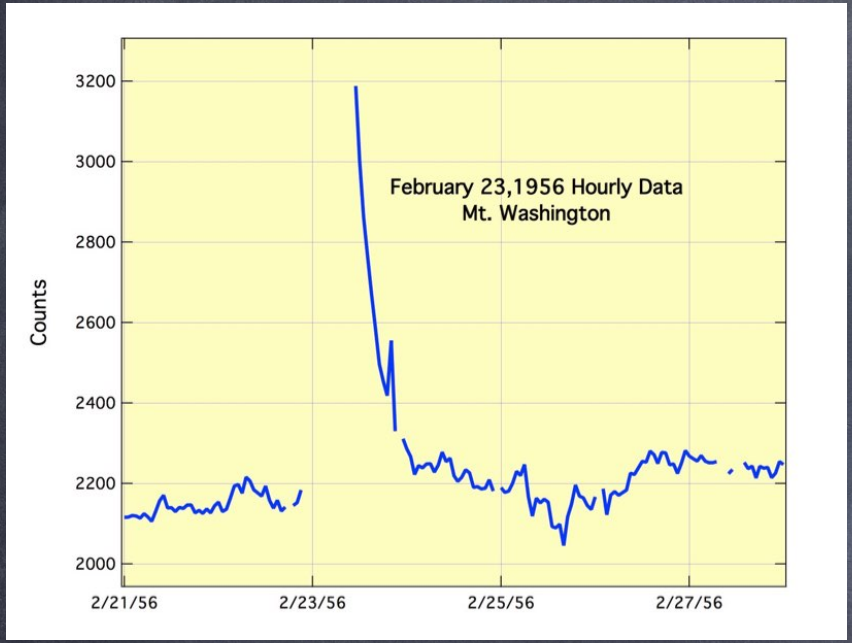


Fig. 12.—Increase of cosmic-ray intensity, November 19, 1949.

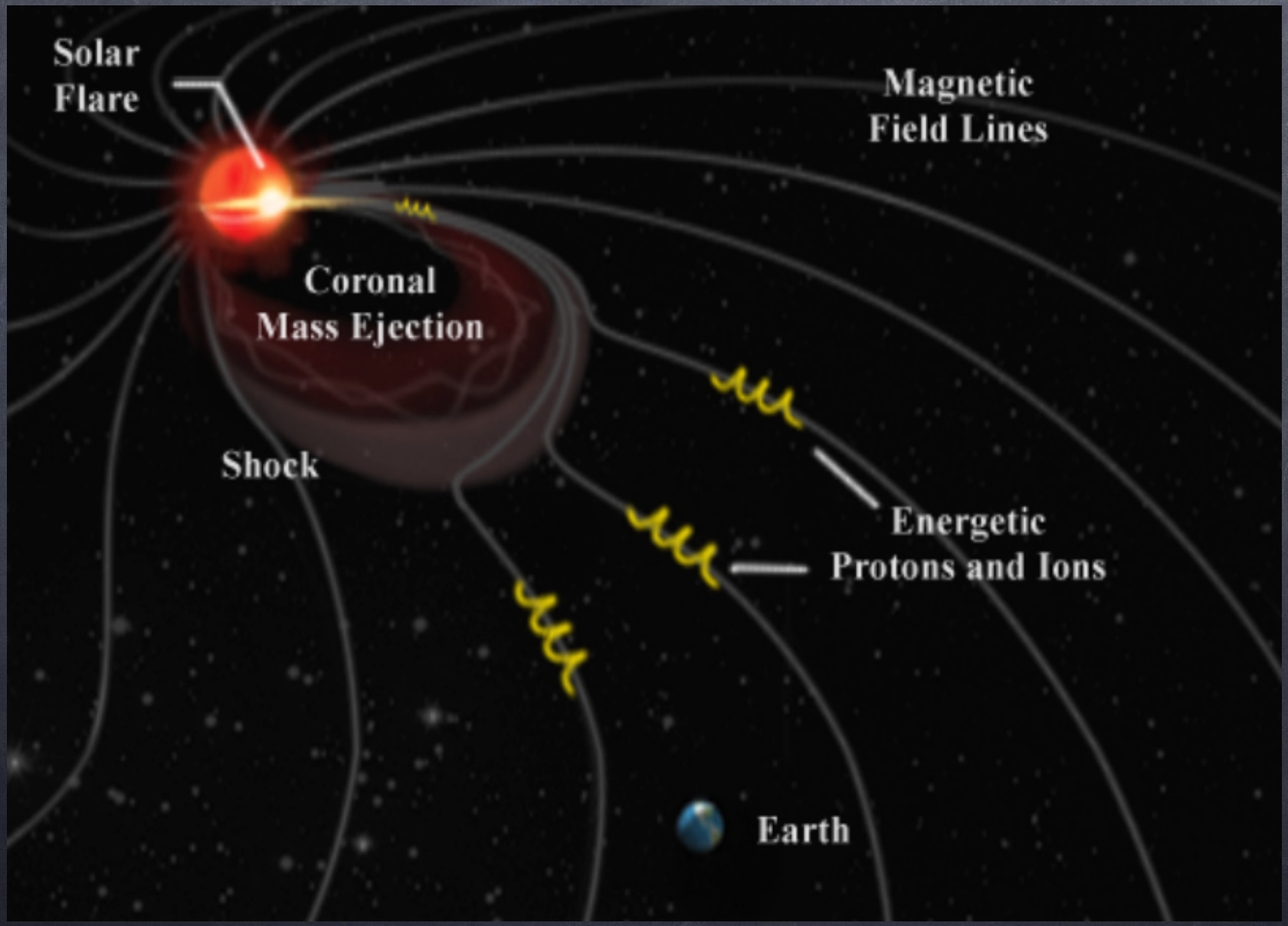


February 23, 1956

Professor Jack Lockwood with the DeMerritt Hall Neutron Monitor, circa 1955

John Lockwood with Durham monitor.

The Big Picture of Transient Solar Phenomena



So who cares?

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The New York Times

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The Long, Strange Trip to Pluto, and How NASA Nearly Missed It

By KENNETH CHANG JULY 18, 2015

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Planetary scientists are coloring in the family portrait of our solar system as close-up photographs and observations stream back from Pluto, a world three billion miles away with towering mountains of ice, vast smooth plains and many mysteries yet to be revealed.

The flyby of Pluto last week by NASA's New

Single Event Upsets in Implantable Cardioverter Defibrillators

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Abstract

Single event upsets (SEU) have been observed in implantable cardiac defibrillators. The incidence of SEUs is well modeled by upset rate calculations attributable to the secondary cosmic ray neutron flux. The effect of recent interpretations of the shape of the heavy ion cross-section curve on neutron burst generation rate calculations is discussed. The model correlates well with clinical experience and is consistent with the expected geographical variation of the secondary cosmic ray neutron flux. The observed SER was 9.3×10^{-12} upsets/bit-hr from 22 upsets collected over a total of 284672 device days. This is the first clinical data set obtained indicating the effects of cosmic radiation on implantable devices. Importantly, it may be used to predict the susceptibility of future implantable device designs to cosmic radiation. The significance of cosmic radiation effects relative to other radiation sources applicable to implantable devices is discussed.

I. Introduction

This paper initially presents a brief review of the sources of radiation relevant to implantable medical devices. The review considers both total dose and transient effects with the aim of determining the relative significance of various sources. The remainder of the paper examines terrestrial cosmic ray single event upset models and their applicability to implantable medical devices. The models are then compared with ICD clinical experience.

II. Summary of Ionizing Radiation Effects on Implantable Devices

Ionizing radiation effects on MOS electronics may be classed into two broad categories [5]:

Total Ionizing Dose Effects (TID) due to charge accumulation in oxide regions: Threshold voltage changes have been seen at around 10 Gy [6] whilst degradation in the isolation between and within n-channel devices may occur at relatively low radiation levels (10-50 Gy) [5]. From these results, it would appear that a reasonable lower bound on the