

# Correlation between Barometric Pressure and Cosmic Ray Intensity

Ashley Batten and Teresa Karr

*Department of Physics, Marian High School, Omaha, NE 68134*

(Submitted 23 March 2001)

Four scintillator detectors recovered from the Chicago Air Shower Array were arranged in a telescope configuration. 3-fold and 4-fold coincidence counts from the detectors were recorded in two hour intervals. Atmospheric pressure was observed using a digital barometer and recorded in thirty second intervals for the duration of each run. An exponential relationship between atmospheric pressure and cosmic ray intensity was determined.

## **Introduction:**

Since their initial discovery by Victor Hess in 1912 [1] there has been continuous research on the nature and sources of cosmic radiation. Primary cosmic rays incident on our atmosphere are charged particles ranging from protons to iron nuclei with traces of heavier elements [2] with protons making up 90% of the total. As they pass through the atmosphere, these primary cosmic rays collide with atmospheric nuclei creating a shower of secondary particles. Ground based detectors then count these secondary particles.

The number of secondaries which reach the surface of the earth is influenced by a number of factors. Five factors which affect the number of particles that are detected are latitude, diurnal cycle, solar activity, Earth weather and barometric pressure/altitude. Arthur Compton demonstrated that the intensity of cosmic radiation is dependent on magnetic latitude in 1933 [3]. Since the sun is one of the primary sources for cosmic rays the daily rotation of the Earth and solar activity have significant impact on the number of cosmic rays which reach the surface of the Earth. Cosmic ray intensity as a function of various solar activities including sunspots and heliospheric structure has been reported by Hall [4]. Rapid changes in cosmic ray intensity measurements have been attributed to Forbush decreases [5] which result from solar flare and coronal mass discharges. Changes in local weather can also influence cosmic ray counters. Aglietta [6] has reported a variation in cosmic ray counts during thunderstorms. He concludes that strong atmospheric electric fields associated with thunderstorms have an effect on the propagation of secondary cosmic ray particles. Finally, cosmic ray intensity is dependent on barometric pressure. A period of high pressure is associated with more absorber above the detector and a lower detection rate results. The purpose of this investigation is to determine the relationship between barometric pressure and cosmic ray intensity.

## **Procedure:**

Scintillator detectors were acquired from the Chicago Air Shower Array (CASA) [6] project. Each detector is constructed of a 61cm x 61cm x 1.27cm acrylic scintillator with a single 5.1 cm diameter photomultiplier tube mounted at the center of one face. Optical coupling between the scintillator and the phototube is maintained by gluing the phototube to the scintillator using an optical glue with the same index of refraction as the acrylic. Modifications to the original CASA detectors included refurbishing and polishing the saw cut ends of the acrylic. The acrylic was also wrapped in foil for this experiment as a prior experiment by Carney et. al. [7] determined that wrapping the detectors in foil improved the efficiency of the detectors by about 15%. Four of these detectors were positioned in a vertical telescope formation as seen in Figure 1. The detectors were placed directly above each other in a wooden rack to allow for a  $71.97^\circ \times 71.97^\circ$  angle of inclusion as seen in Fig. 2.



Figure 1: Photograph of Detector Telescope

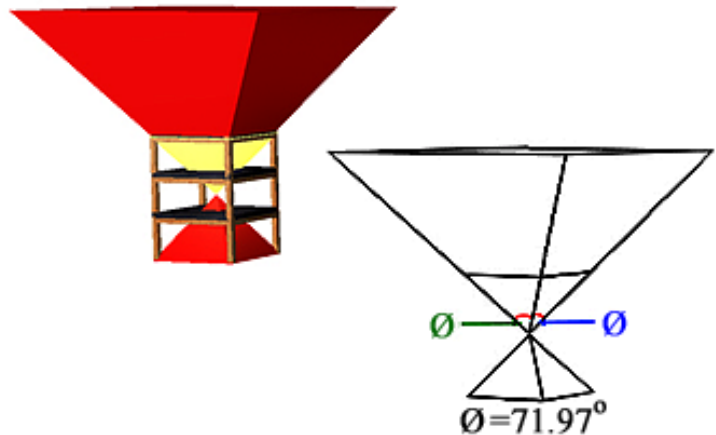


Figure 2: Angle of Inclusion for telescope above.

Operating voltage for the PMT's was set at 1350 V and the discriminator threshold was set at 80mV based on prior experiments with these detectors [8]. Discriminator output width was set to 100ns. A digital barometer [9] (see figure 3) was interfaced with a computer and the program Logger Pro was used to plot Time (in hours) v. Pressure (in mmHg) for each run.



Figure 3: Barometer with Analog to Digital Converter.

Each run consisted of counting 3-fold and 4-fold coincidences for a two hour period. Simultaneous with the count, the barometric pressure was measured at thirty second intervals. The average barometric pressure was then plotted v 3-fold and 4-fold coincidences. It was observed that during some runs the variation in barometric pressure was significant. It was concluded that if the standard deviation of the barometric pressure over the two hour period exceeded 1.0 the run would be discarded.

#### Data Analysis and Results:

The results of the 3-fold coincidence experiment over months January and February are as shown in Fig. 3:

Figure 3:  
3-fold coincidence v barometric pressure  
January-February 2001

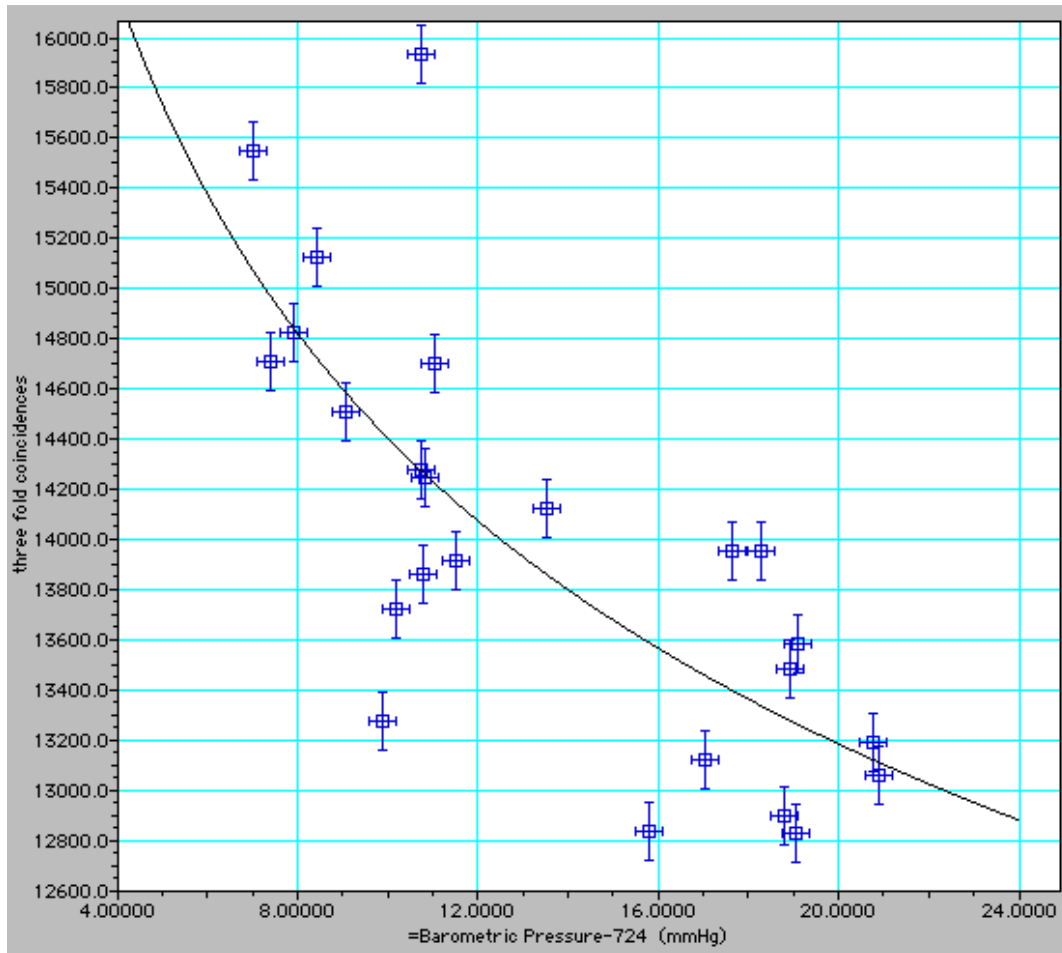
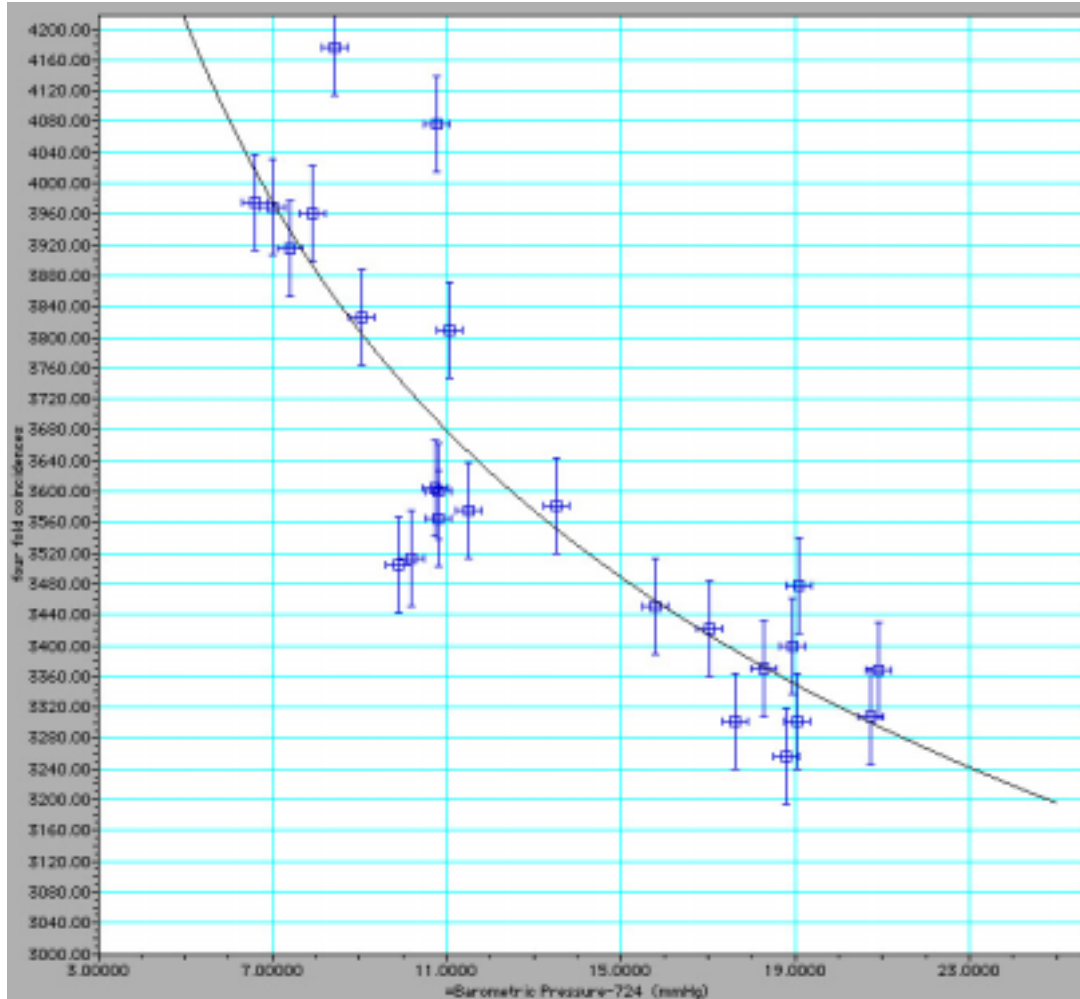


Figure 4:  
4-fold Coincidence v Barometric Pressure  
January-February 2001



**Discussion:**

Atmospheric pressure is the force exerted upon the earth by the atmosphere. More specifically, it is the force exerted by the column of air above us. When barometric pressure increases, the distance between the particles in the air decreases. This causes an increase in the density of particles. Thus, the cosmic rays traveling through the atmosphere have a greater chance of colliding with the particles on their way to earth. These collisions result in electromagnetic or hadronic showers in which a shower of secondary particles is emitted. Because of the increased interactions of the cosmic rays, they have a greater chance of being changed into a particle that does not reach the earth or is not detectable by the CASA detectors.

The above graphs of the effect of barometric pressure on 3-fold and 4-fold coincidences illustrate this hypothesis.

The relationship between the barometric pressure and the intensity of cosmic rays was found to be exponential.  
The general form of the equation is:

$$N = N_0 e^{-b(p)} \quad (1)$$

Where N = coincidence for given value of pressure

$N_0$  = highest count, determined from graph

b = the rate of decrease

p = pressure

For the 3-fold coincidence data the empirical equation matching the graph is:

$$N = 15894 e^{-0.01(p)}$$

This equates to a percent decrease of 1.0% per mm of Hg

And for the 4-fold coincidence data the empirical equation is:

$$N = 4288 e^{-0.013(p)}$$

This equates to a percent decrease of 1.3% per mm of Hg

These results compare to the findings of Wilson[10] who reported the incidence of muons was shown to decrease by 0.35% per millimeter of Hg and Clay [11] who reported a decrease of 0.2% per millibar or 1.5% per mm of Hg in an experiment performed in Australia.

- [1] Hess, V.F., 1912 Z. Physics. 13, 1084.
- [2] Cronin, J.W., 1999 Review of Modern Physics. 71 5165.
- [3] Compton, A.H., 1933 Physics Review. 43. 387
- [4] Hall, D.L. Humble E Dulig, 1994 PASA. 11, 2, 170
- [5] Yanchukovsky, V.L. Aug. 1999 International Cosmic Ray Conference. “Forbush-decreases in cosmic rays for March and October, for data of spectrograph on the basis of neutron monitor”.
- [6] Gibbs, K.G., Nuclear Instruments & Methods in Physics Research. A 264 (1988) 67-73.
- [7] Carney, A., Fendrick, T., Greer, E. Internal Publication 2001. “The Effect of Foil Wrapping on Scintillator Efficiency”.
- [8] Carney, A., Fendrick, T., Greer, E. Internal Publication 2001. “Discriminator Thresholds”.
- [9] 1) Barometer from Vernier  
2) ULI from Vernier  
3) Logger Pro from Vernier
- [10] Wilson, J.G., Cosmic Rays. (1976) 35-36.
- [11] Clay, R.W. Electronic Publications of the Astronomical Society of Australia. Feb. 2000, Vol. 17, Number 2. “A Cosmic Ray Muon Detector for Astronomy Teaching”.