Scholarly activity atop Mt. Evans since 1930

Dr. Bob Stencel, University of Denver
Professor of Astronomy & Director of DU Observatories
Department of Physics & Astronomy
A briefing for USFS-CCRD, May 22, 2007 & 5/23/06, 5/24/05
Outline

• Yesterday
  1930s: Origins of cosmic ray [CR] research
  1946 – 1960s: CR boom years
  1972: the first telescope on site
  1980s: increased environmental research
  1994: proposal to upgrade the observatory

• Today
  Current Programs, Challenges and Opportunities

• Tomorrow
  FAQs
EIGHT SCIENTISTS START MOUNT EVANS COSMIC RAY EXPEDITION

Caravan Heads for Summit Lake to Study Mysterious and Continual Bombardment of Earth; Eclipse Will Have No Effect.

(By GENE LINDBERG.)

While other scientists Tuesday were waiting in tense anticipation for Wednesday's eclipse of the sun, a caravan of eight scientific men left Denver headed for Summit Lake on Mount Evans.

Since these men are students of cosmic, not solar rays, the eclipse, Wednesday, will be little more than an interesting incident.

When the moon's shadow sweeps across the United States they will be at work setting up and adjusting delicate instruments, observing the downpour of rays more mysterious than sunlight, and entirely independent of sun energy.

EARTH BOMBADED CONTINUOUSLY BY RAYS.

Night or day, in fair weather or foul, in eclipse or in broad daylight, the penetrating cosmic rays continue to bombard the earth.

Heading the Mount Evans party are Drs. J. C. Stearns of Denver University, and Ralph D. Bennett of Cambridge, Mass., coworkers with Dr. Arthur H. Compton of Chicago in a worldwide checkup of cosmic rays.

Bennett and his party have just returned from Alaska.

They brought with them the instruments used on the towering peaks of the far north. The result of their observations will mean a direct, accurate comparison of cosmic ray intensity at Summit Lake, as compared with similar altitudes in Alaska.

WILL PROVIDE DOUBLE CHECK.
Development of cosmic-ray air showers

Primary particle (e.g. iron nucleus)

first interaction

pion decays

second interaction

CR air showers

(C) 1999 K. Bernlöhr
Cosmic rays and lightning
For his discovery of the effect of X-ray scattering on electrons, **Compton was awarded the Nobel Prize in Physics for 1927** (sharing this with C. T. R. Wilson who received the Prize for his discovery of the cloud chamber method).

During 1930-1940, Compton led a world-wide study of the geographic variations of the intensity of cosmic rays, thereby fully confirming the observations made in 1927 by J. Clay from Amsterdam of the influence of latitude on cosmic ray intensity. He could, however, show that the intensity was **correlated with geomagnetic rather than geographic latitude. This gave rise to extensive studies of the interaction of the Earth's magnetic field with the incoming isotropic stream of primary charged particles.**
LETTERS TO THE EDITOR

Prompt publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this depart-

Variation of the Cosmic Rays with Latitude

Definite differences in the intensity of the cosmic rays at different latitudes are shown by our measurements, which have ranged from 47° north to 46° south. As far as they have gone, these measurements indicate a uniform variation with latitude, showing a

Table I. Cosmic ray intensity at different localities
(Ions per cc per sec. through 5 cm Pb, 2.5 cm Cu and 0.5 cm Fe)

<table>
<thead>
<tr>
<th>Location</th>
<th>Lat.</th>
<th>Long.</th>
<th>Elev.</th>
<th>Barom.</th>
<th>$I_C$</th>
<th>$I_L$</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mt. Evans</td>
<td>40° N</td>
<td>106° W</td>
<td>14,200ft</td>
<td>17.6 fin</td>
<td>6.88 ions</td>
<td>0.57</td>
<td>9/31</td>
</tr>
<tr>
<td>Denver</td>
<td>39° N</td>
<td>106° W</td>
<td>5,000</td>
<td>24.8</td>
<td>2.93</td>
<td>0.56</td>
<td>9/31</td>
</tr>
<tr>
<td>Jungfraujoch</td>
<td>47° N</td>
<td>6° E</td>
<td>11,400</td>
<td>19.70</td>
<td>5.68</td>
<td>0.51</td>
<td>10/31</td>
</tr>
<tr>
<td>Heidelberg</td>
<td>21° N</td>
<td>156° W</td>
<td>9,000</td>
<td>21.47</td>
<td>3.35 ± 0.05</td>
<td>0.60</td>
<td>4/32</td>
</tr>
<tr>
<td>Idje-welde</td>
<td>21° N</td>
<td>156° W</td>
<td>4,200</td>
<td>25.99</td>
<td>2.40 ± 0.05</td>
<td>0.37</td>
<td>4/32</td>
</tr>
<tr>
<td>Honolulu</td>
<td>21° N</td>
<td>158° W</td>
<td>70</td>
<td>40.09</td>
<td>1.89 ± 0.02</td>
<td>0.11</td>
<td>4/32</td>
</tr>
<tr>
<td>S. S. Aorangi</td>
<td>4° S</td>
<td>173° W</td>
<td>60</td>
<td>29.65</td>
<td>1.83 ± 0.05</td>
<td>0.32</td>
<td>4/32</td>
</tr>
<tr>
<td>Southern Alps</td>
<td>44° S</td>
<td>170° E</td>
<td>6,000</td>
<td>23.69</td>
<td>3.39 ± 0.05</td>
<td>0.22</td>
<td>4/32</td>
</tr>
<tr>
<td>Southern Alps</td>
<td>44° S</td>
<td>170° E</td>
<td>3,000</td>
<td>26.10</td>
<td>2.70 ± 0.04</td>
<td>0.21</td>
<td>4/32</td>
</tr>
<tr>
<td>Dunedin</td>
<td>46° S</td>
<td>170° E</td>
<td>80</td>
<td>30.08</td>
<td>2.16 ± 0.03</td>
<td>0.11</td>
<td>4/32</td>
</tr>
<tr>
<td>Wellington</td>
<td>41° S</td>
<td>173° E</td>
<td>400</td>
<td>29.85</td>
<td>2.16 ± 0.03</td>
<td>0.12</td>
<td>5/32</td>
</tr>
</tbody>
</table>

Hopfield and Dr. E. O. Wollan, Professor J. C. Stearns of the University of Denver with J. A. Longman, L. N. Ridonour and W. Overbeck made the measurements at Denver and Mt. Evans. Dr. Marcel Schein and Dr. Bernhard Frey of the University of Zurich cooperated.

Without the cordial cooperation of the various universities where the work has taken us, the measurements would have been much more difficult.

ARTHUR H. COMPTON
University of Chicago,
The Tasman Sea,
May 7, 1932.
Modern cosmic ray telescopes

High energy gamma ray sources impact atmospheric nuclei and spawn air showers detectable as light flashes in the night sky.

& Henderson mine underground cosmic ray lab proposed 2007
FROM THE LOGBOOK OF THE MT. EVANS LAB  
1936

Progress Report of the Mt. Evans Laboratory
Pictures of the Construction.  B. Hoyt

All work stopped because of Snow Storm.

The Gables shown on the top of joist sections after the Snow Storm.
1938


THE MOUNT EVANS LABORATORY

By Professor J. C. STEARNS

UNIVERSITY OF DENVER

The construction of Mount Evans Laboratory was begun in May, 1936, and the laboratory was first used for scientific work on June 28, 1937. For those whom this laboratory may serve, the following description of the location, climate, physical plant and policy of operation of the laboratory, as well as the events leading to its establishment, will be of interest.

In September, 1931, A. H. Compton did his first field work in cosmic rays at Summit Lake, which is 1,000 feet below the peak on Mt. Evans. Cosmic ray intensity measurements were made on Mt. Evans for a brief period at this time. The apparatus used was constructed at the University of Chicago and transported to Colorado in an enclosed bus, which served as a cosmic ray laboratory for this first work. The rigors of the climate were such that, with the lack of adequate protection, a trick on the night shift was equivalent to a polar expedition. This expedition was followed by others headed by R. D. Bennett, Massachusetts Institute of Technology; T. H. Johnson, Bartol Research Foundation; J. C. Street, Harvard; D. K. Froman, McDonald College of McGill University; and J. C. Stearns, of the University of Denver.

These early workers and their associates used tents for laboratories and living quarters. The wind velocity at night was often sufficient to level tents and scatter equipment. The fire hazard prevented safe heating of tents, and the indoor temperatures often fell to 30 degrees F. or lower. Both apparatus and workers were without protection from the frequent electric storms.

The intensity of cosmic rays at the alti-
1939

Rocky Mtn News

1939 Feb 26:

“...the world’s highest little red schoolhouse... it’s importance may have been manifested by the fact that only Nobel prize winners in physics in the US have been those who made studies on this suitable location...”

D. U. Lab

On Mt. Evans

Study Cosmic Rays

At Top of Peak

On the peak of Mount Evans is the world’s highest “little red schoolhouse.” This lofty institution is considered part of the University campus, for it is here that the science departments conduct exclusive cosmic experiments!

The structure was built in 1936 in Denver and transported to the location by segments. It consists of two rooms, one used as the laboratory and the other as living quarters. It had to be constructed such a manner as to withstand 150 mile per hour wind velocity and to prevent electrical storms from disturbing the experiments. It was made windproof, sidewalks eliminated, while the protection from lightning was given by surrounding the building with metal connected to ground wires.

This “little red schoolhouse” has meant more to the country than just “reading, ’riting, ’rithmetic.” Its importance has been manifested by the fact that the only Nobel prize winners in physics in the United States have been those who made studies on this suitable location. The laboratory will be of significant importance in research on cosmic rays. It is impossible to make the prolonged accurate observations at such an
Dr. Bruno Rossi was an authority on cosmic rays and professor of physics at the Massachusetts Institute of Technology. He started his academic career at the University of Florence and held the chair in physics in Padua from 1932 to 1938, when the Fascist regime dismissed him.

He also discovered that individual cosmic rays, colliding with atoms, often generated large numbers of secondary particles, known as showers. His findings gave evidence of the astonishing energies associated with cosmic rays.
1948, Life magazine article

COSMIC RAY RESEARCH
SEVEN COLLEGES JOIN TO STUDY NATURE'S MIGHTIEST FORCE

WITH A COLORADO MOON SHINING DOWN ON HIS TENT LABORATORY, A PHYSICIST SPENDS THE NIGHT WATCHING HIS INSTRUMENTS RECORD COSMIC RAYS

PHOTOGRAPHS FOR LIFE BY JOHNNY FLOREA
1948

On the high slopes of Mount Evans cosmic ray hunters assemble two-ton spheres of steel with which to record traces of the particles.

DeSTRUCTION OF NUCLEUS by a primary cosmic ray can result in the creation of any of the known subatomic particles. Above: a primary proton, moving at almost the speed of light, approaches the nucleus of a nitrogen atom in the atmosphere (left). As the proton collides with it (center), the nucleus cracks open and flies apart, forming in this particular case a heavy alpha particle, a proton (P), a neutron (N) and two mesons (right)—the latter apparently created out of nothing at all but actually formed by the sudden conversion into matter of the tremendous binding energy which originally held particles of this nucleus together.
ON SUMMIT of Mt. Evans, Physicist Bernard Gregory and a girl friend, who works at the Crest House below them at right, relax after a climb. Building serves as restaurant for many scientists.

SCIENTISTS LIKE THE RUGGED LIFE

Despite the serious nature of their research, the cosmic ray scientists managed to create a kind of outing atmosphere in their bleak mountain camps. Most brought their families with them for the summer months. Since living facilities at the three main camp sites (map, above) were meager, most scientists lived in trailers or tents. One resourceful wife heated water for washing on one of the big electromagnets. Children playing around the equipment sometimes became a problem: one 3-year-old child burned his britches when he sat down on a hot transformer. For recreation, husbands and wives played bridge or took hikes along mountain trails. Even during working hours the scientists were not above a little fun. Dressed in a protective waterproof suit worn in the hunt for cosmic rays on icy Summit Lake, Dr. Mario Iona of the University of Denver plunged into the water and paddled placidly about like an overturned turtle (opposite).
During these decades, an international cadre of cosmic ray researchers came to Echo Lab & Mt. Evans. DU’s manager for much of this work was Prof. Mario Iona.
II. Current Programs, 1972 & on

- Astronomy
- Biology
- Environmental sciences
- Atmospheric studies
- Cosmic ray studies

http://www.du.edu

Denver Post
1973 July 3
The “new” Observatory, 1997
following an EA process, 1994-5

Meyer-Womble Observatory, Oct. 1996
Mt. Evans, Colorado (14,148 ft. elev.)
University of Denver - Astronomy

Photo by Peter Grannis (c) with permission
A look inside:

WORLD'S HIGHEST OBSERVATORY
DU's planned telescope on Mount Evans summit, elevation 14,264 feet.

**Clear Viewing**
A vent system will draw air from around the telescope and vent it away from the building to provide a stable, distortion-free view. Ports to draw air will be positioned throughout the dome, including several recycled Saab sunroofs. The telescope and its support structure are water-cooled to equalize them to the surrounding temperature.

**Telescope**
The telescope will have two 28.5-inch "eyes" to conduct simultaneous observations in the near and mid-infrared wavelengths. It will be able to compensate for atmospheric turbulence and will be fully computer-controllable. To minimize vibration, it will be mounted atop two steel pillars to isolate it from the building structure.

**Remote access**
A radio link will connect the observatory to observers and computers on campus, 50 miles away. It will allow remote control of the telescope, when not operated through the computer workstations in the observatory. Eventually, this radio link will allow the public and schools to connect and view telescope images.

MOUNT EVANS SUMMIT
The Meyer binocular telescope
“Ours is a vision quest, looking into the ultimate Wilderness, seeking the campfires of creation.”
--Phil Rastocny, guest observer, Chippewa tribe
Students &
guest
observers
Science at the Summit

Our Atmosphere

- The summit of Mt. Evans places you above 40% of the earth’s atmosphere and 90% of the water vapor present at sea level.

- Water vapor is one of the major greenhouse gases. Should global warming be occurring, water vapor levels will begin to rise like steam in a hot shower, and this effect can be sensitively measured from Mt. Evans.

- Infrared monitoring of the atmosphere have been conducted from this site since the 1950s. This record will help evaluate the long-term effects of society’s emissions of carbon dioxide and chlorofluorocarbons.

Astronomy

- Telescopes at high altitudes have less of the hazy atmosphere to look through, providing a clearer view of the “cosmic wilderness” above the Earth.

- The dome near the Crest House contains a 24 inch telescope built in 1973. The site is operated by the University of Denver, under a USFS Special Use permit.

- Research conducted from this telescope includes study of the life cycle of stars -- from their birth in cold interstellar clouds, to their fiery deaths as supernovae. DU astronomers are investigating these and related phenomena. Additional information is on display near the dome itself.

Cosmic Rays

- Cosmic rays are charged particles from the Sun and deep space that constantly rain down on earth at nearly the speed of light and with tremendous energy.

- Cosmic rays can shatter atoms in our upper atmosphere, like miniature high-energy “atom smashers”. Some showers of by-products can reach the ground and cause a range of effects, from charging the air to biological mutation.

- The dense atmosphere near sea level shields life from cosmic rays, but not at high altitudes, where the air is thinner.

- Mt. Evans has been a research site for cosmic ray physics, since the 1920s.
Earth & atmosphere

The big 3

Cosmic rays

Space sciences, renewable energy & more…
Science at the Summit

Astronomy
Telescopes at high elevations look through less haze in the atmosphere than telescopes at sea level. This provides a clearer view of the "cosmic address" above the earth.

Researchers from Denver University use a telescope to study the life cycle of stars, from their birth in cold interstellar clouds to their death as supernovas.

Our Atmosphere

The summit of Mt. Evans places you above 40% of earth's atmosphere and 80% of earth's water vapor. If global warming is occurring, water vapor levels in the atmosphere should begin to rise, like steam in a hot shower.

Using infrared cameras, researchers have been monitoring atmospheric pollution from Mt. Evans since the 1950s. These studies help evaluate the long-term effects from human-produced emissions of carbon dioxide and chlorofluorocarbons.

Cosmic Rays

Charged particles, called cosmic rays, constantly rain down on the earth. As nearly the speed of light and with tremendous energy, these rays shatter atoms in our upper atmosphere. Some by-products of these collisions reach the earth's surface, resulting in chemical or biological mutations.

Dense atmosphere at sea level shields life from cosmic rays, whereas thin atmosphere at high elevations does not offer the same protection. Cosmic ray research has occurred at Mt. Evans since the 1950s.
Professional, external research guests at DU's Mt. Evans Observatory (other than astronomers)

2007 -- Dan Birkenheuer, Ph.D.
NOAA Earth System Research Laboratory
high-altitude water vapor and radiance data

2006 -- Bob Musselman
Rocky Mountain Research Station
USDA Forest Service, Ft.Collins
continuous ozone monitor

2005 -- Brenda L. Dingus
Los Alamos National Lab
cosmic ray, photometric tube testing at altitude

continued on next slide ➔
2004 -- David R. Lincks
Senior Test Engineer, ReliOn Inc.
Avista Labs performing an altitude test on fuel cell system

2003 -- Daniel Winester, Geodesist
NOAA - NOS - National Geodetic Survey
absolute gravity measurements, tectonics

2003 -- Keith Emery, Calibration Scientist
National Renewable Energy Lab
NREL absolute cavity intercomparison

Prior years:
NASA - Cassini Venus encounter observational support
Univ. Alaska - sprites lightning support observations
SouthWest Research Lab - near earth asteroid observation
We collect sunlight during the day, so we can collect starlight at night...
In the sky – summer 2007

• Evening star, setting = VENUS
  (June & July - up to 48 degrees from the Sun)
• Evening star, rising = JUPITER
  * Perseid meteor shower Aug. 11-12-13:
    (best at/after midnight, moon phase=NEW!)
• Total lunar eclipse Aug. 28, 3am-sunrise
• & surprises!
Challenges

“Everything up here is experimental…”

Access…

Power…

Light pollution…

Summit parcel special use permit expires 2015.
The Vanishing Colorado Night Sky…

Denver from Mt. Evans, 2003 June, 2 min exp., 400ASA, 28mm lens, (c) Mark Cunningham
### Light Pollution Map, centered on Mt. Evans

<table>
<thead>
<tr>
<th>Color</th>
<th>Artificial / Natural Sky Brightness</th>
<th>Sky Brightness mags / sq arcsec</th>
<th>Description (Courtesy of Russell Sipe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.01</td>
<td>&gt;21.6</td>
<td></td>
<td>Natural sky brightness</td>
</tr>
<tr>
<td>0.01 to 0.11</td>
<td>21.6 to 21.5</td>
<td></td>
<td>Long exposure astrophotos might show some light pollution gradient, but visual observing is relatively unimpaired.</td>
</tr>
<tr>
<td>0.11 to 0.33</td>
<td>21.5 to 21.3</td>
<td></td>
<td>Milky Way shows structure</td>
</tr>
<tr>
<td>0.33 to 1.0</td>
<td>21.3 to 20.8</td>
<td></td>
<td>Milky Way not visible</td>
</tr>
<tr>
<td>1.0 to 3.0</td>
<td>20.8 to 20.1</td>
<td></td>
<td>Serious impact to deep sky observing and imaging. Milky Way visible but not crisp.</td>
</tr>
<tr>
<td>3.0 to 9.0</td>
<td>20.1 to 19.1</td>
<td></td>
<td>Milky Way not visible</td>
</tr>
<tr>
<td>9.0 to 27.0</td>
<td>19.1 to 18.0</td>
<td></td>
<td>Less than 100 stars visible over 30 degrees elevation</td>
</tr>
<tr>
<td>&gt;27.0</td>
<td>&lt;18.0</td>
<td></td>
<td>Hopeless?</td>
</tr>
</tbody>
</table>

*http://cleardarksky.com/lp/DenverCOlp.html*
How much energy loss?  **Measured:** ~100 MEGAWATTS
Approximately 5% of Xcel production [5000+ MW]

View of metro Denver from western foothills, Aug. 1999
Note cloud brightness due to metro lights.
(This is ~5% Xcel/PSCo,  ~100% Calif shortfall)
Cumulative effects:
Wasted lighting energy, from uplighted signs...

...and unshielded lamps
→ glare & trespass
**GLARE:**
discomforting and disabling, esp. for older folks

**LIGHT TRESPASS:**
The light sources are to the left in this picture -- ... *is this a good neighbor?*
Before and after shielding lamps

Plenty of light, just much better aimed!
To summarize...

YOU CANNOT STAY ON THE SUMMIT FOREVER:
YOU HAVE TO COME DOWN AGAIN...
SO WHY BOTHER IN THE FIRST PLACE?
JUST THIS: WHAT IS ABOVE KNOWS WHAT IS BELOW,
    BUT WHAT IS BELOW DOES NOT KNOW
    WHAT IS ABOVE.
ONE CLIMBS, ONE SEES.
ONE DESCENDS, ONE SEES NO LONGER
    BUT ONE HAS SEEN.
THERE IS AN ART OF CONDUCTING ONESELF
    IN THE LOWER REGIONS BY THE MEMORY
    OF WHAT ONE SAW HIGHER UP.
WHEN ONE CAN NO LONGER SEE,
    ONE CAN AT LEAST STILL KNOW.

RENE DAUMAL
III. Summit FAQs

The Big 3 questions:

• Where are the restrooms?
• Where are the mountain goats?
• When is the observatory open to the public?
Answer: D.U. campus observatory in south Denver, open year-round

A continuing tradition of education and public outreach, since 1880!
Thanks for listening.

Questions?