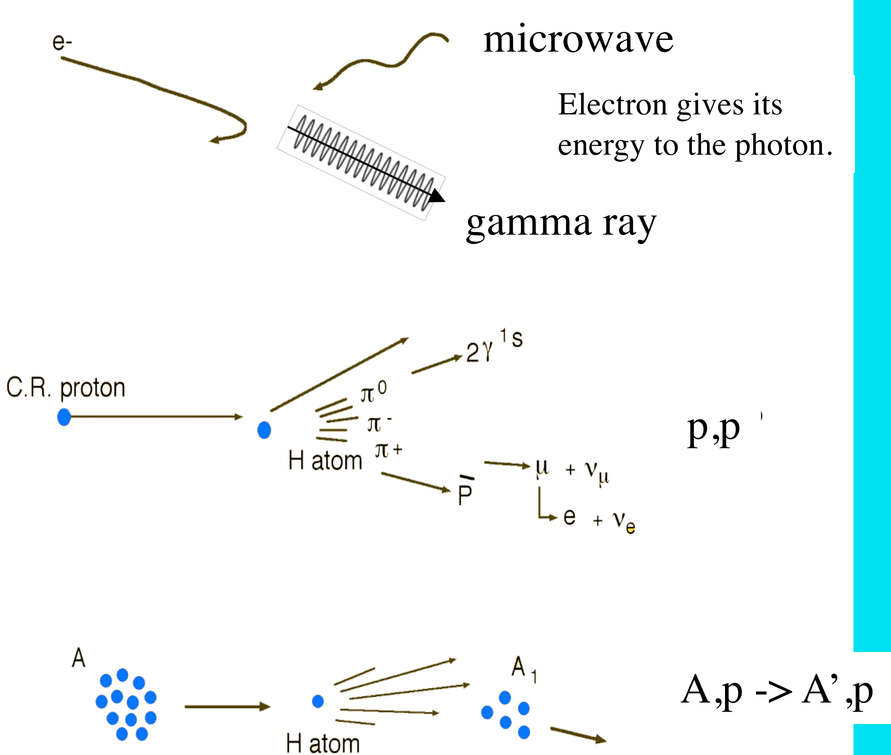
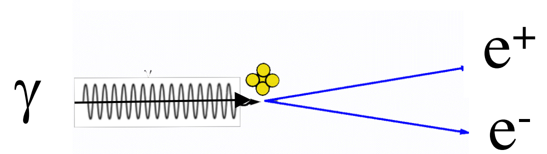
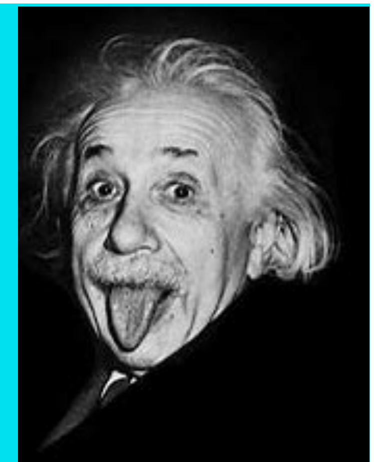
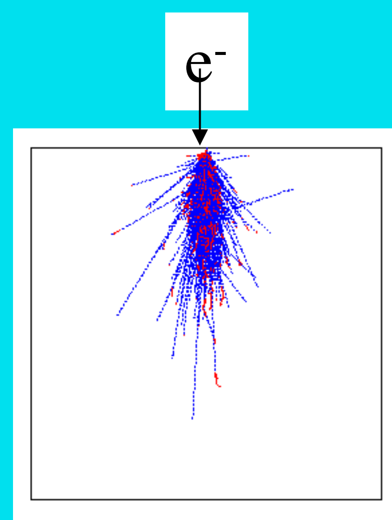
COSMIC RAY INTERACTIONS

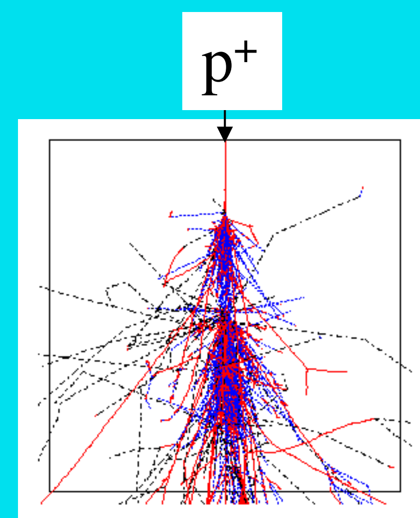




$$E = mc^2$$

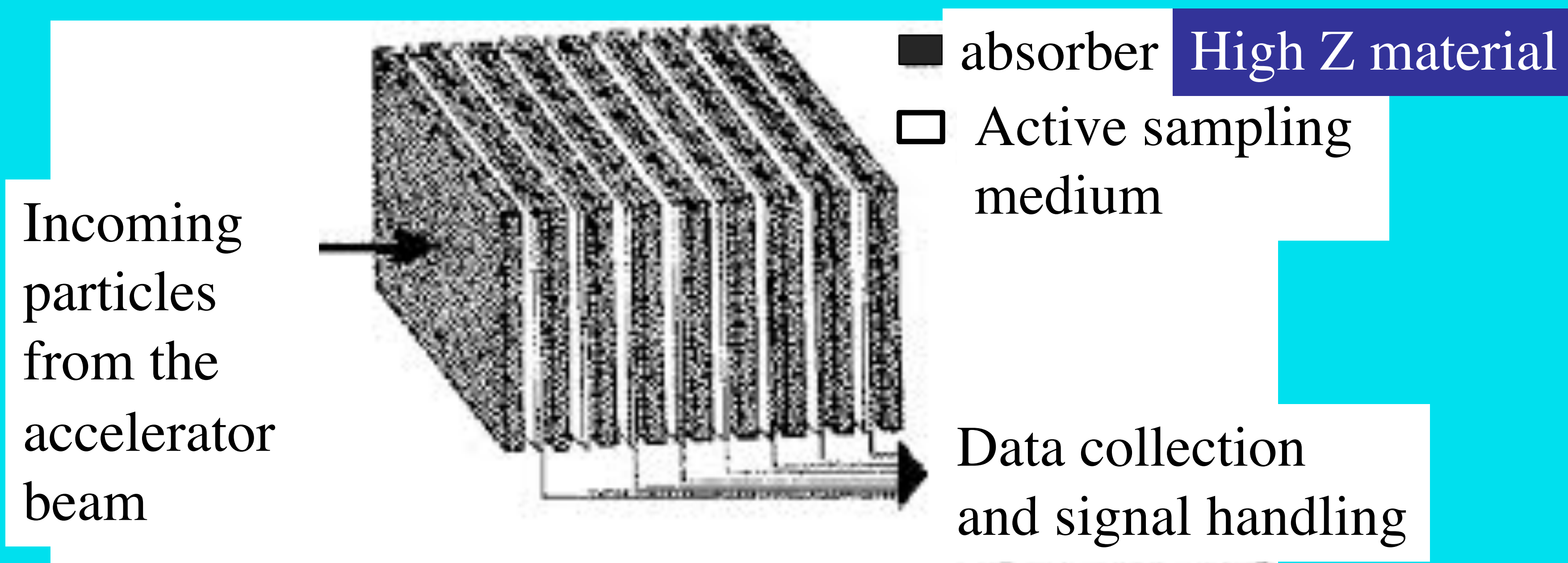


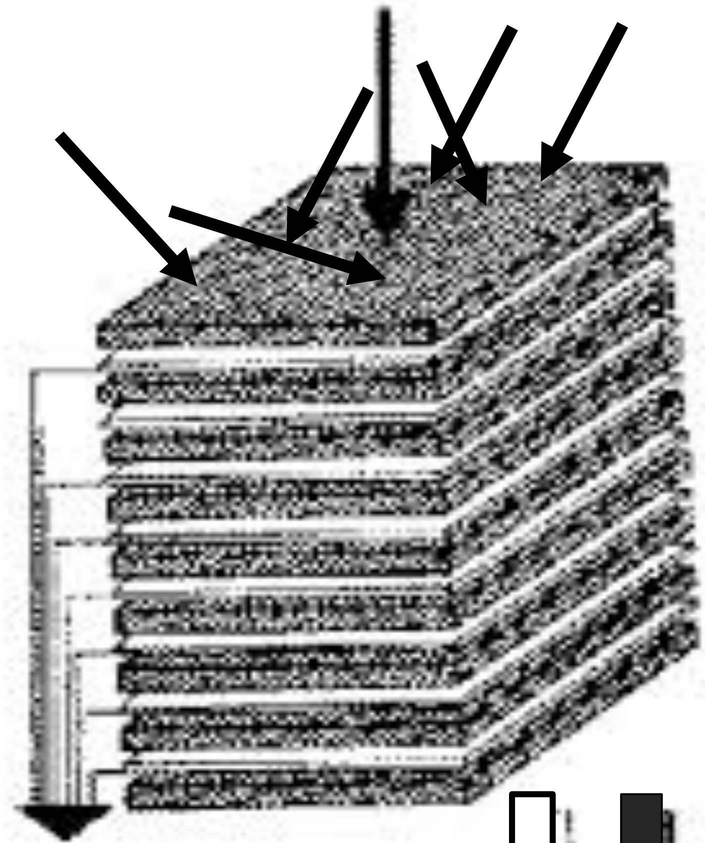




Block of matter

We built a sampling "calorimeter" like those being used at high energy particle accelerators





Incoming cosmic rays from the sky are isotropic; they come in equal numbers from all directions.

Measure signal in the sampling layers

We built a sampling "calorimeter" to measure the energy of cosmic rays above a few GeV

Detectors on top

- Measure direction of incoming particle to correct signals in calorimeter sampling layers for angle of incidence

- Measure charge of the incoming particles

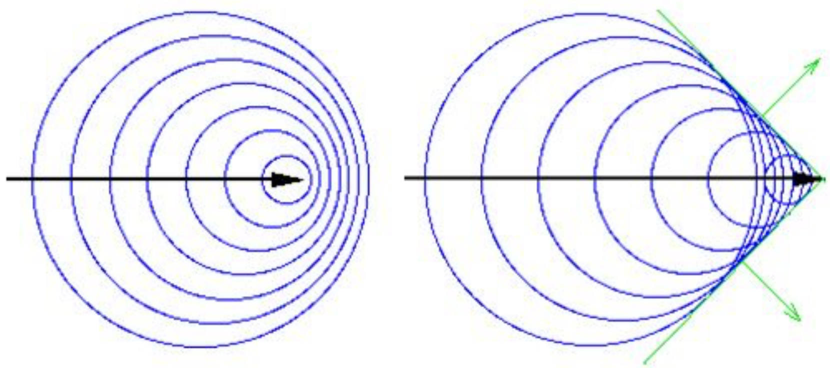
- Used scintillators

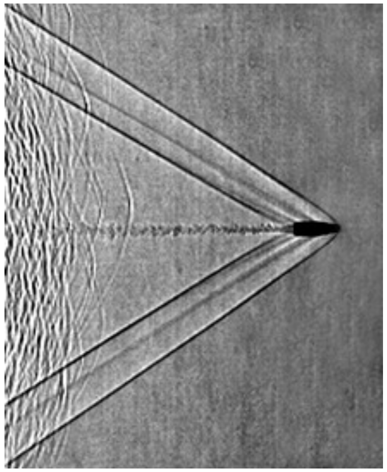
- Used Cherenkov detectors

Recall slides on ionization loss

Slow particle; no bow shock forms

Example:
Boat moving slowly, no bow wave behind
Boat moves faster than the speed of the waves in water, shock forms



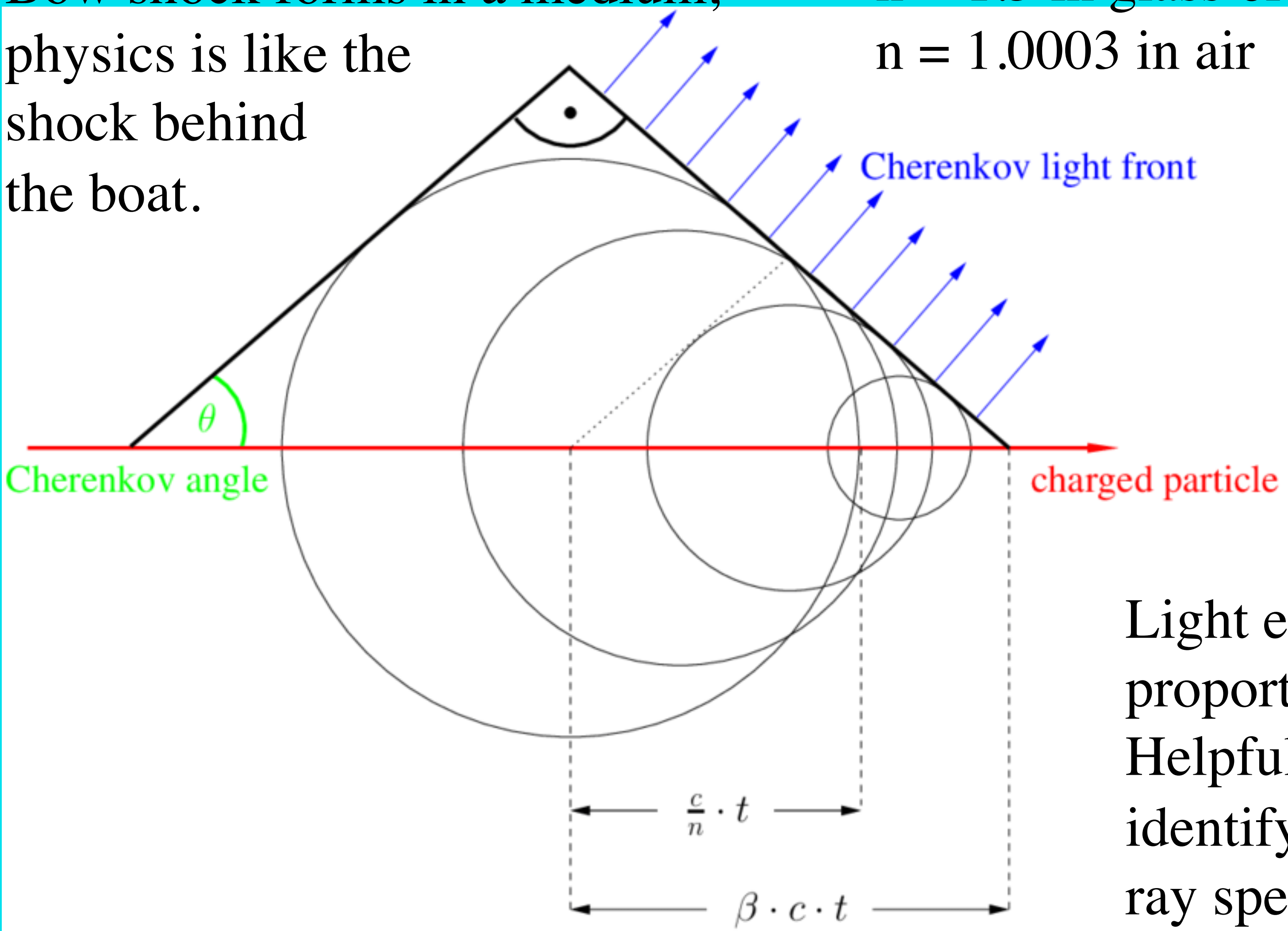


Cherenkov effect

v > c/n where n is the index of refraction of the medium

Bow shock forms in a medium; physics is like the shock behind the boat.

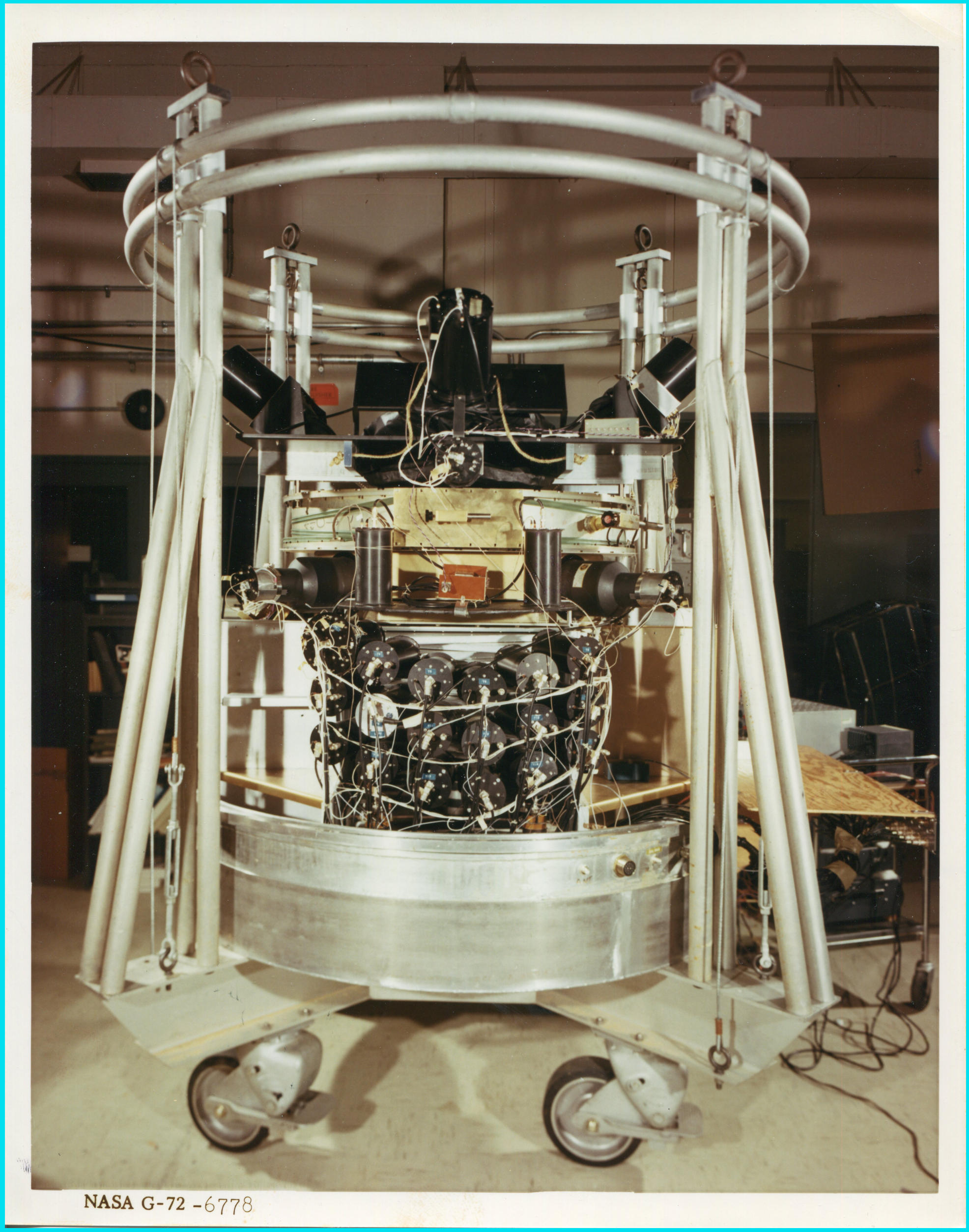
n = 1.5 in glass or plastic
n = 1.0003 in air



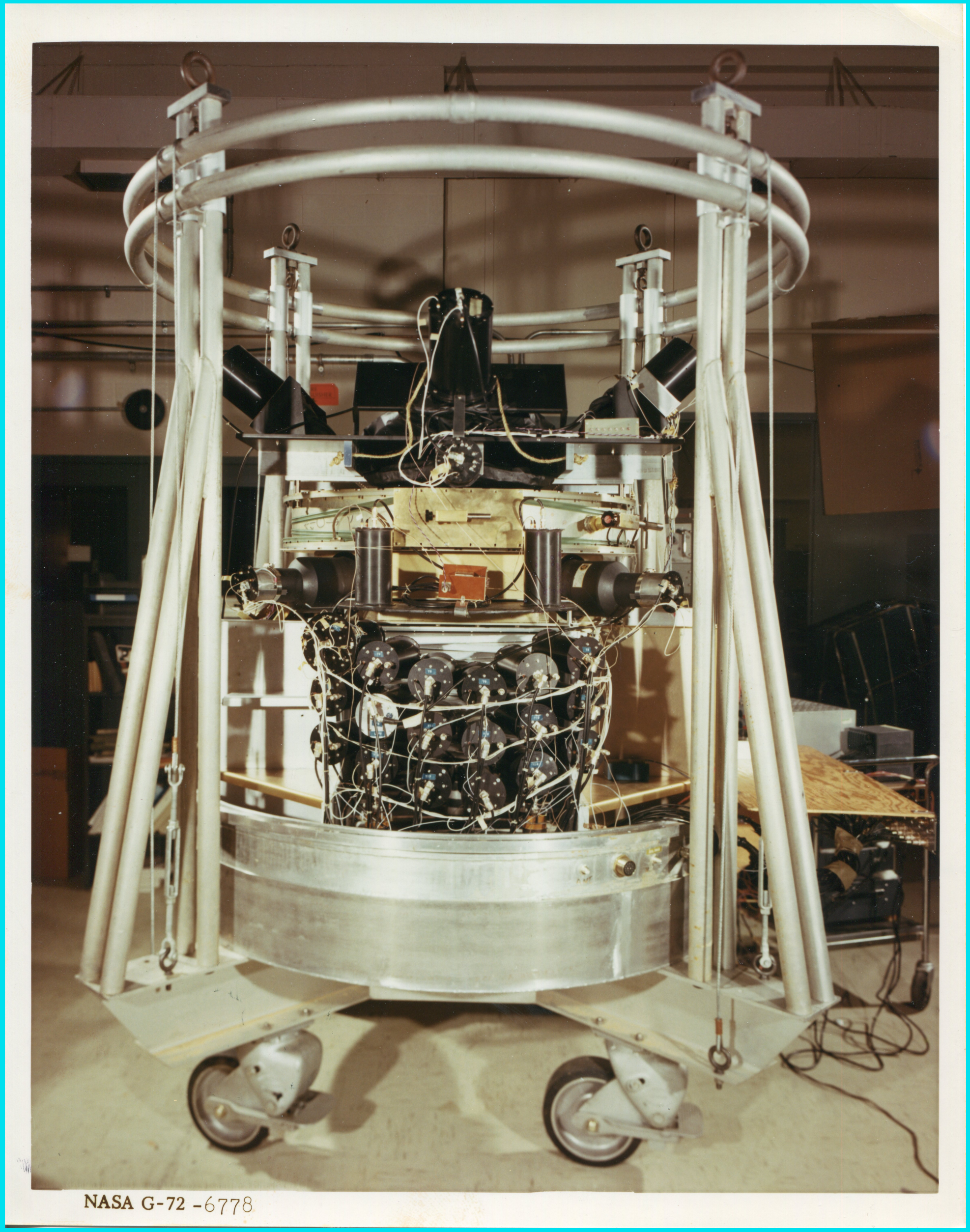
Light emitted proportional to Z^2. Helpful for identifying cosmic ray species.

By 1972, our payloads had grown somewhat.

And they would keep on growing!



The lower portion of this payload is the iron calorimeter. You can see the black cans that held the photomultipliers. They viewed the light signals from the scintillators that counted the particles. From the signals we could determine the energy of each particle hitting the apparatus. This experiment stood for many years as the definitive measurement of the spectra of individual high energy cosmic rays.



At GSFC we were a lot more ambitious than I was as a graduate student.

Big News Story Goes Up, Up, Up And Away

It squirreled down from the heavens about 3 a.m. Friday over Highway 70, 13 miles southwest of Orangeburg as three T&D staffers watched in amazement and disbelief. It was odd-shaped and in trouble.

THE CRAFT appeared to be without a pilot as it headed for earth at a modest but determined pace in the pre-dawn sky. Not a sound was heard until the plastic-like tail began ripping the tree tops.

The woods and nearby fields came alive with mild explosions resembling a fusillade of pistol shots. Nobody moved until the shooting was over.

It was an eerie spectacle. A weird phenomenon — and it was about to land.

A STORY was in the making. People from outer space were invading Orangeburg County!

As two of the staffers rushed to a corner of the field to witness the landing, disappointment replaced the expectancy in the air. The flight wasn't over.

Almost as if it had been a planned hedge-hopping, but with a bit of embarrassment, the giant weather balloon regained its composure, pulled in its dangling cords and swiftly climbed back into the moonlit sky.

THREE STUNNED earth men watched the big data bag disappear over a sleeping Orangeburg and drove back to the T&D office without the story that might have been.

Nov. 14, 1970

Big News Didn't Get Away Entirely, Yet

The "weather balloon" spotted Friday morning by three Times and Democrat staffers has turned out to be much more than expected.

According to an Air Force spokesman, the balloon was carrying over 5,000 pounds of intricate equipment to collect data on cosmic radiation. Most of the instruments were found Saturday near Norway and the Air Force plans to recover them Sunday.

It was launched at Holloman AFB, N.M., at 8:30 EST p.m. Wednesday. The balloon, which continued on its merry way after dumping its gondola of equipment, was last reported about 700 miles from Bermuda.

The Times and Democrat hopes to carry pictures and a complete story of today's recovery in Monday's edition.

Nov 15, 1970

1052 transportation Company (Lt-Med Truck)
South Carolina National Guard
Orangeburg, South Carolina

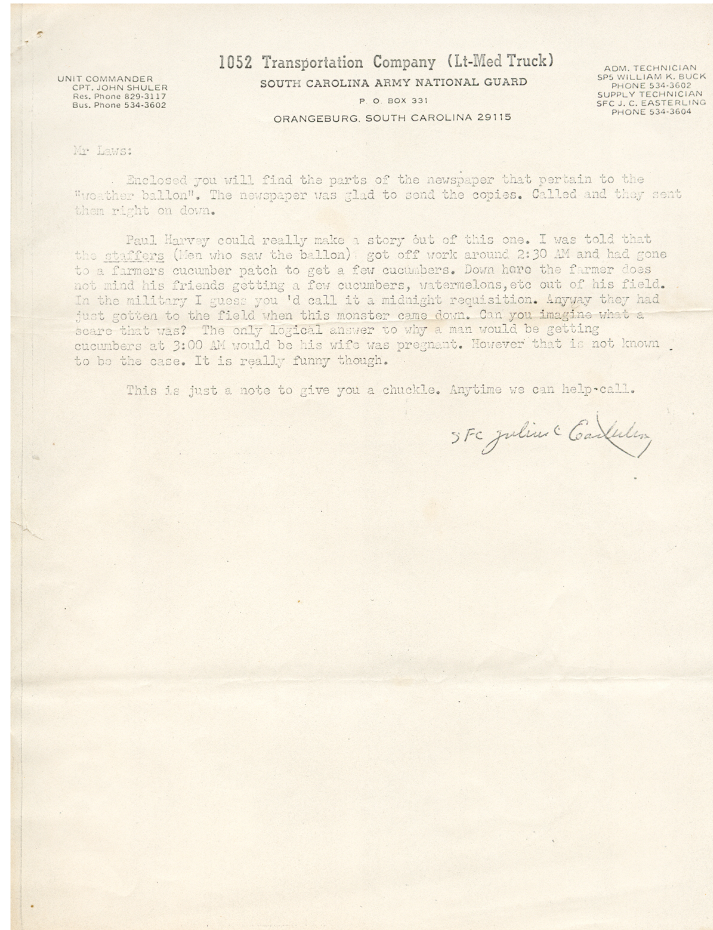
Mr. Laws:

Enclosed you will find the parts of the newspaper that pertain to the “weather ballon”. The newspaper was glad to send the copies. Called and they sent then right on down.

Paul Harvey could really make a story of this one. I was told that the staffers (Men who saw the ballon) got off work around 2:30 AM and had gone to a farmers cucumber patch to get a few cucumbers. Down here the farmers does not mind his friends getting a few cucumbers, watermelons, etc. out of his field. In the military I guess you’d call it a midnight requisition. Anyway they had just gotten to the field when this monster came down. Can you imagine what a scare that was? The only logical answer to why a man would be getting cucumbers at 3:00 AM would be his wife was pregnant. However that is not known to be the case. It is really funny though.

This is just a note to give you a chuckle. Anytime we can help, call.

SFC Julius Easterling
South Carolina National Guard



UNIT COMMANDER
CPT. JOHN SHULER
Res. Phone 829-3117
Bus. Phone 534-3602

1052 Transportation Company (Lt-Med Truck)
SOUTH CAROLINA ARMY NATIONAL GUARD
P. O. BOX 331
ORANGEBURG, SOUTH CAROLINA 29115

ADM. TECHNICIAN
SP5 WILLIAM K. BUCK
PHONE 534-3602
SUPPLY TECHNICIAN
SFC J. C. EASTERLING
PHONE 534-3604

Mr Laws:

Enclosed you will find the parts of the newspaper that pertain to the "weather ballon". The newspaper was glad to send the copies. Called and they sent them right on down.

Paul Harvey could really make a story out of this one. I was told that the staffers (Men who saw the ballon) got off work around 2:30 AM and had gone to a farmers cucumber patch to get a few cucumbers. Down here the farmer does not mind his friends getting a few cucumbers, watermelons,etc out of his field. In the military I guess you 'd call it a midnight requisition. Anyway they had just gotten to the field when this monster came down. Can you imagine what a scare that was? The only logical answer to why a man would be getting cucumbers at 3:00 AM would be his wife was pregnant. However that is not known to be the case. It is really funny though.

This is just a note to give you a chuckle. Anytime we can help-call.

SFC Julius C Easterling

The “staffers” said nothing to anyone until the payload was found a day or two later. Then this story came out but not in the newspaper!

Nov. 16

emocrat
sperity
EBURG, S.C., 29115
10 CENTS DAILY 15 CENTS SUNDAY

THE WEATHER

South Carolina: Fair and continued cold Monday and Monday night. High Monday in the 50s, low Monday night around 30.

NOW LET'S SEE! — Airmen and members of the Orangeburg National Guard decide on the best way to remove a 5,000-pound gondola from a wooded area near Norway. A heavy-duty wrecker from the local Guard unit was employed to pull the huge instrument package onto the roadside about 100 feet away.

Giant Balloon's Scientific Data Safe Again Now

By RICHARD DeWITT
Of The Times and Demcorat

NORWAY, S. C. — An Air Force crew, with the help of several members of the Orangeburg National Guard and four or five Norway residents, Sunday reclaimed the payload of a giant balloon near here.

The gondola, weighing about 5,000 pounds and carrying intricate equipment to measure, record and transmit data on cosmic radioactivity at extremely high altitutes, crashed into a wooded are about 13 miles southwest of Orangeburg approximately 100 feet off Highway 70 about 3 a.m. Friday.

SEVERAL SMALLER instrument boxes

NOW LET'S SEE! — Airmen and members of the Orangeburg National Guard decide on the best way to remove a 5,000-pound gondola from a wooded area near Norway. A heavy-duty wrecker from the local Guard unit was employed to pull the huge instrument package onto the roadside about 100 feet away.

Giant Balloon's Scientific Data Safe Again Now

By RICHARD DeWITT
Of The Times and Demcorat

NORWAY, S. C. — An Air Force crew, with the help of several members of the Orangeburg National Guard and four or five Norway residents, Sunday reclaimed the payload of a giant balloon near here.

The gondola, weighing about 5,000 pounds and carrying intricate equipment to measure, record and transmit data on cosmic radioactivity at extremely high altitutes, crashed into a wooded are about 13 miles southwest of Orangeburg approximately 100 feet off Highway 70 about 3 a.m. Friday.

PATH OF DESTRUCTION — This downed pine tree shows the force with which a gondola from an high-altitude Air Force research balloon hit near Norway early Friday morning. It cleared a six-foot path through a quarter mile of woods before coming to a stop.

SEVERAL SMALLER instrument boxes were recovered in the swamps of the South Edisto River several miles away.

A heavy-duty wrecker from the National Guard was used to pull the gondola onto the roadway and load it into an Air Force truck.

According to Maj. Joe Koehy, who headed the six-man Air Force team in Orangeburg, the flight began at 3:30 p.m. EST at Holloman AFB, N.M., near the famed White Plains Testing Range.

Its trajectory was to take it up to 108,000 feet, terminating east of Texarkana, Ark. Due to a malfunction in the insturmentation package, Major Koehly said, the balloon floated eastward over Memphis, Tenn. Birmingham, Atlanta, and Augusta, setting off a series of unidentified flying objects reports.

HE SAID THE helium in the dirigible contracted in the cold air early Friday morning and it crashed. The gondola cleared a six-foot path for almost a quarter of a mile, knocking over at least one big pine tree, before coming to a rest. The balloon then broke away and continued on its merry way, being last reported about 700 miles from Bermuda.

Major Koehly and his crew have been following the object since Thursday and light aircraft were used extensively over this area Friday and Saturday.

Three Times and Democrats staffers heard the crash, saw the airbag regain altitute, but assumed it was only a weather balloon.

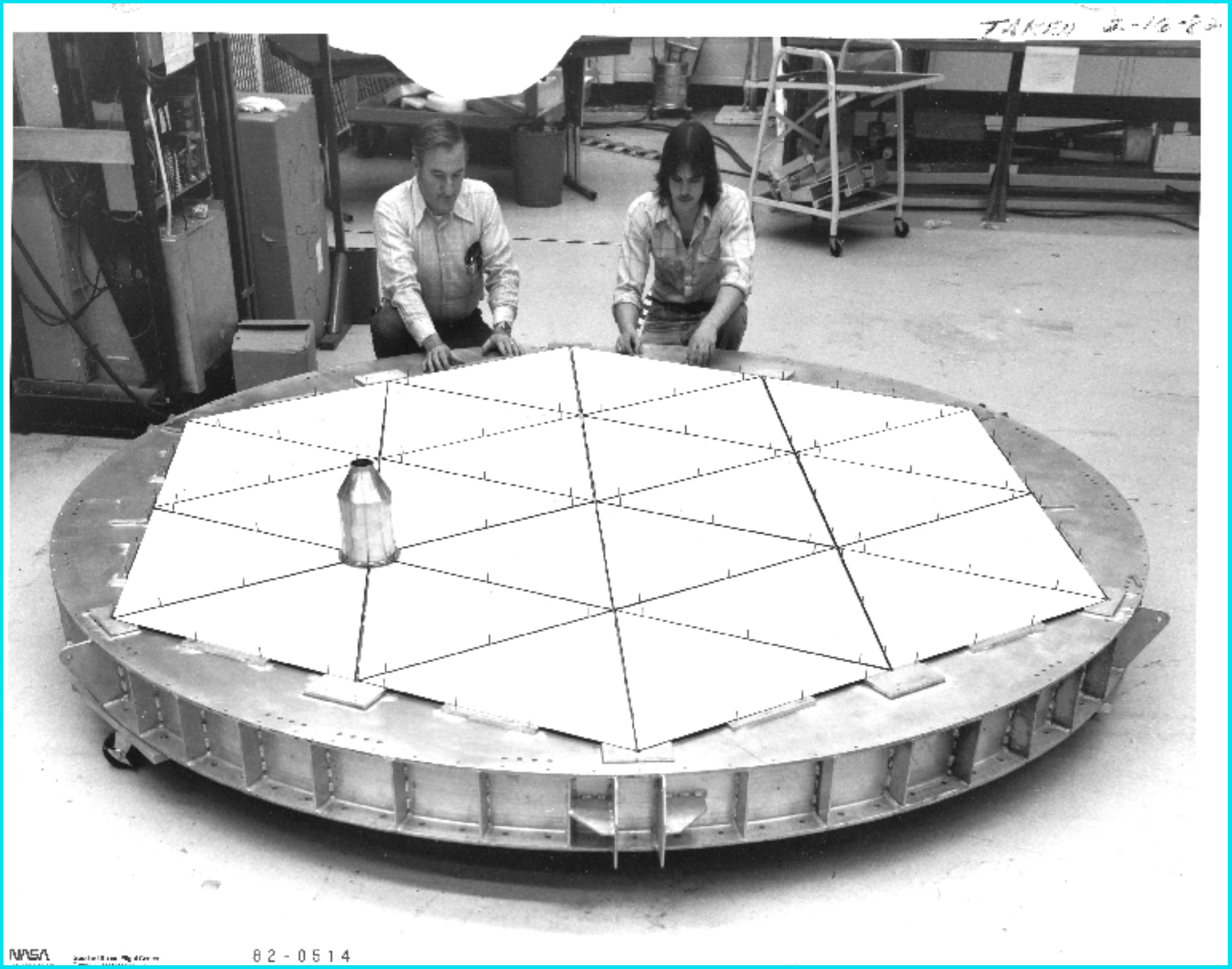
G. L. Williams of Norway notified the Air Force Saturday morning that he had found one of the packages in a swampy area. The major then went to the Orangeburg Fire Department to borrow hip boots for his crew to use in the recovery.

Firemen informed him of a story about the incident in Saturday's edition of the T&D. A staff reporter accompanied Major Koehly and SSgt. Robert Glover to the site of the crash, but several deer hunters, including Thomas Godowns Jr. and Chuck Baldwin, were waiting for them near the gondola.

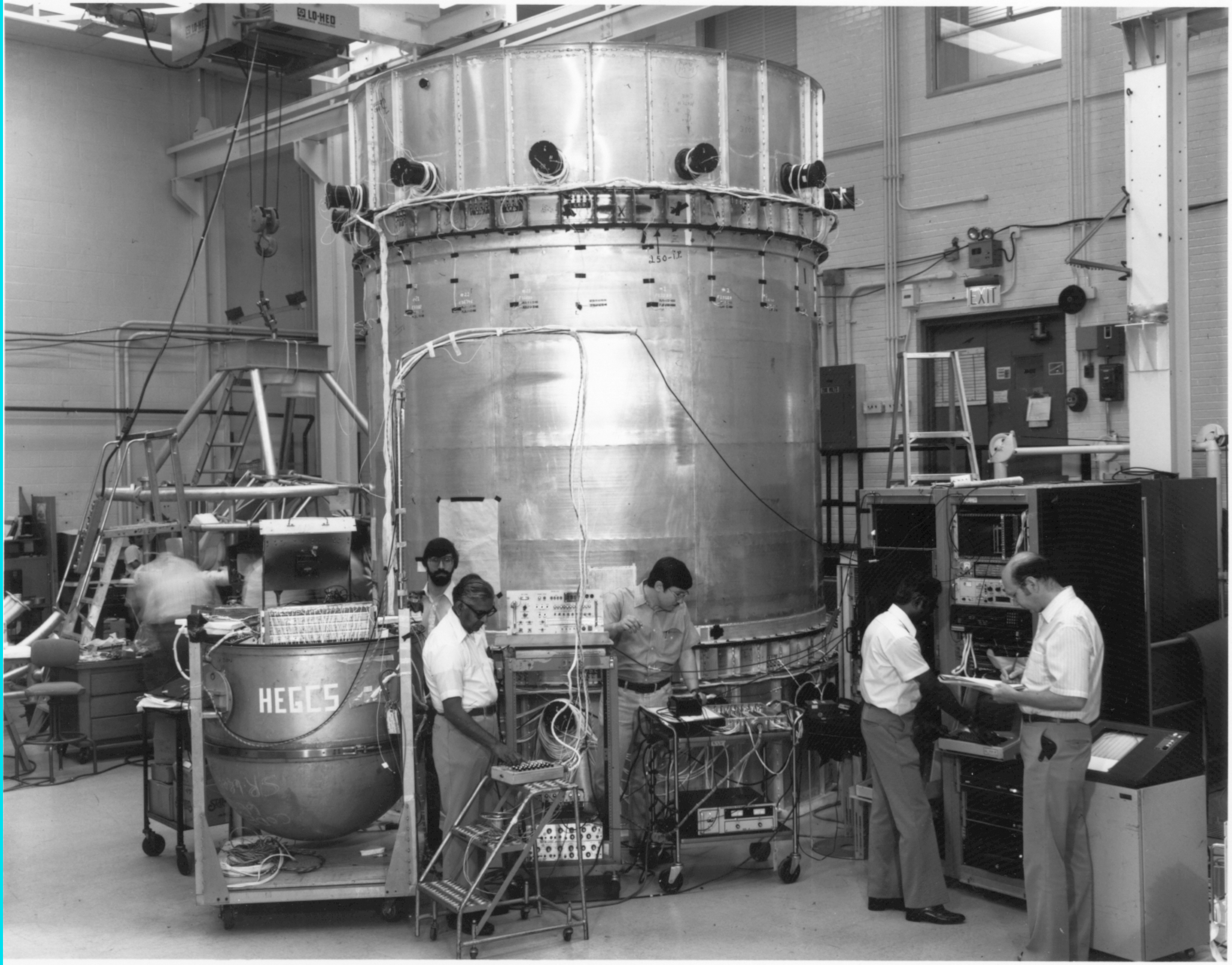
TOTAL HEIGHT of the balloon, parachutes and instruments at the time of launch was about 610 feet, the major said, with the largest part of the airbag measuring 420 feet in diameter. His crew, Detachment 1, Air Force Cambridge Research Laboratory, launches about 80 balloons a year. "We have never lost one," Major Koehly said, "We stay until we find them."

Only visible damage to the gondola was a few scratches and dents. It is now at the Orangeburg National Guard Armory, awaiting a decision whether to ship it back to New Mexico or to its manufacturer in Maryland.

High Energy Gas Cherenkov Spectrometer



We tried to invent a new word, but it didn't stick – Entopistic, Greek for position determining, so an Entopistic scintillator

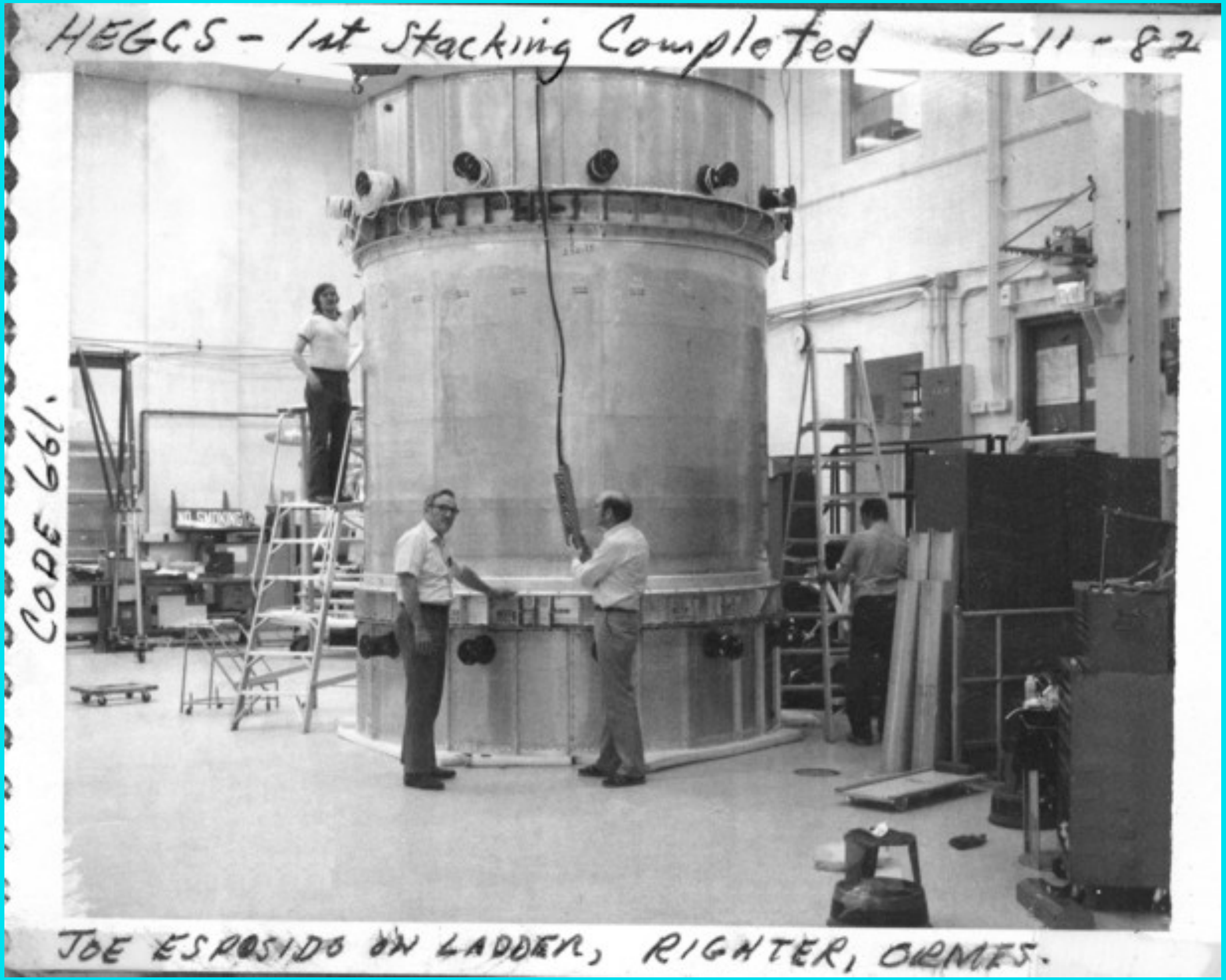


Goddard Space Flight Center
Greenbelt, Maryland 20771

82-5268

Higher the energy the fewer the number of particles per square meter per unit time. We kept trying to make larger area detectors and have them fly for longer times.

"Are you going to fly that mother on a balloon?"
GSFC Director, Noel Hinners



High Energy Gas Cherenkov Spectrometer (HEGCS)

```
  EVENT #    61583: NT, NB =  5   24: COSINE =  0.925: LCERT =   1
H( 1)= 115   H( 2)= 115   H( 3)= 107   H( 4)= 122   H( 5)= 105   H( 6)= 120
H( 7)= 100   H( 8)= 118   H( 9)= 100   H(10)= 121   H(11)= 130   H(12)= 133
 TOP HAT AVE =   116  ZTOP =  14.6  TWASC ARRAY :  1 1 1 1 1 1 1 1 1 1 1 1

C( 1)=  47   C( 2)= 251   C( 3)= 307   C( 4)=  55   C( 5)=  -1   C( 6)=  87
C( 7)= 165   C( 8)=  52   C( 9)=   0   C(10)= 155   C(11)=  37   C(12)=  55
C(13)=   7   C(14)=  25   C(15)=  74   C(16)=  33   C(17)=  41   C(18)=  -1
C(19)= 101   C(20)=  -2   C(21)= 235   C(22)=   0   C(23)=   0   C(24)=  -2

 CSUM(1)=   746  CSUM(2)=   464  CSUM(3)=   179  CSUM(4)=   332   GAS C TOTAL=  1721   AVERAGE=   72.04

H( 1)= 134   H( 2)= 100   H( 3)=  93   H( 4)=  93   H( 5)=  89   H( 6)=  96
H( 7)= 100   H( 8)= 108   H( 9)= 114   H(10)= 115   H(11)= 127   H(12)=  77
 BOT HAT AVE=   106  ZBOT =  14.0  TWASC ARRAY:  1 1 1 1 1 1 1 1 1 1 1 0

TOP TRIANGLE ARRAY: GAIN=1.0              BOTTOM TRIANGLE ARRAY: GAIN=1.0

          4       -1       3                       0       0       0

      3      978      4       0                0       0       0       0

  1       30      49       1       1       4       6       2       0       2

      1       1       3       1                45     972      1       0

          1       1       0                       51       0       2
```

ecks
ives

campus claimed the life of
-old youth after his motor-
uck a median, skidded
) feet and struck a light
e youth was taken to
rt Medical Center where he
t 4 a.m. His name is being
pending notification of his

l 5:45 p.m. Friday evening,
motorcycle accident on
ines Road left a 26-year-
veport man seriously in-

T. Moses of 4302 N. Market
616, was seriously injured
motorcycle was struck by
olet Camaro driven by
Nelson, 63, of 1604 David
oad. Nelson was reportedly
nto his driveway when the
e ran into his car.
was taken to LSU Hospital
was listed in stable con-

itions were issued in the ac-

ondale,
follow

– would garner the necess-
thirds vote to come away
prize.
ion leaders were to cast
epresenting 14.5 million
-file unionists. About 9
otes would put the winning
e over the top.
andidate got two-thirds of
through two ballotings, the
oard would declare that no
been endorsed.
EA is not affiliated with the

gusta, Maine, Sens. Glenn
lobbed verbal grenades at
Democratic presidential
ll in Maine — while Mon-
ed the event would solidify
ling as the party frontrun-

planned to join four other
es today before 2,000 del-
xpected to cast most of their
ing ballots for Mondale.
s not participating.
Cranston of California and
of South Carolina, jockey-
a third-place finish today,
e on the ballot. Former Sen.
McGovern of South Dakota,
mer, also was seeking votes
not on the ballot.
some competitors en-
d speculation that Glenn
lace second despite his low

Look what just dropped in ...

Photo by J. Frank McAneny

Residents of the Grawood area check out an unexpected visitor which dropped from the sky into the trees near their house Friday night. The payload of a research balloon launched in Palestine, Texas, bore an instrument box and a large smiling jack-o'-lantern face on the 5,000-pound object's orange plastic covering.

It came from the sky

Experimental apparatus lands south of Shreveport

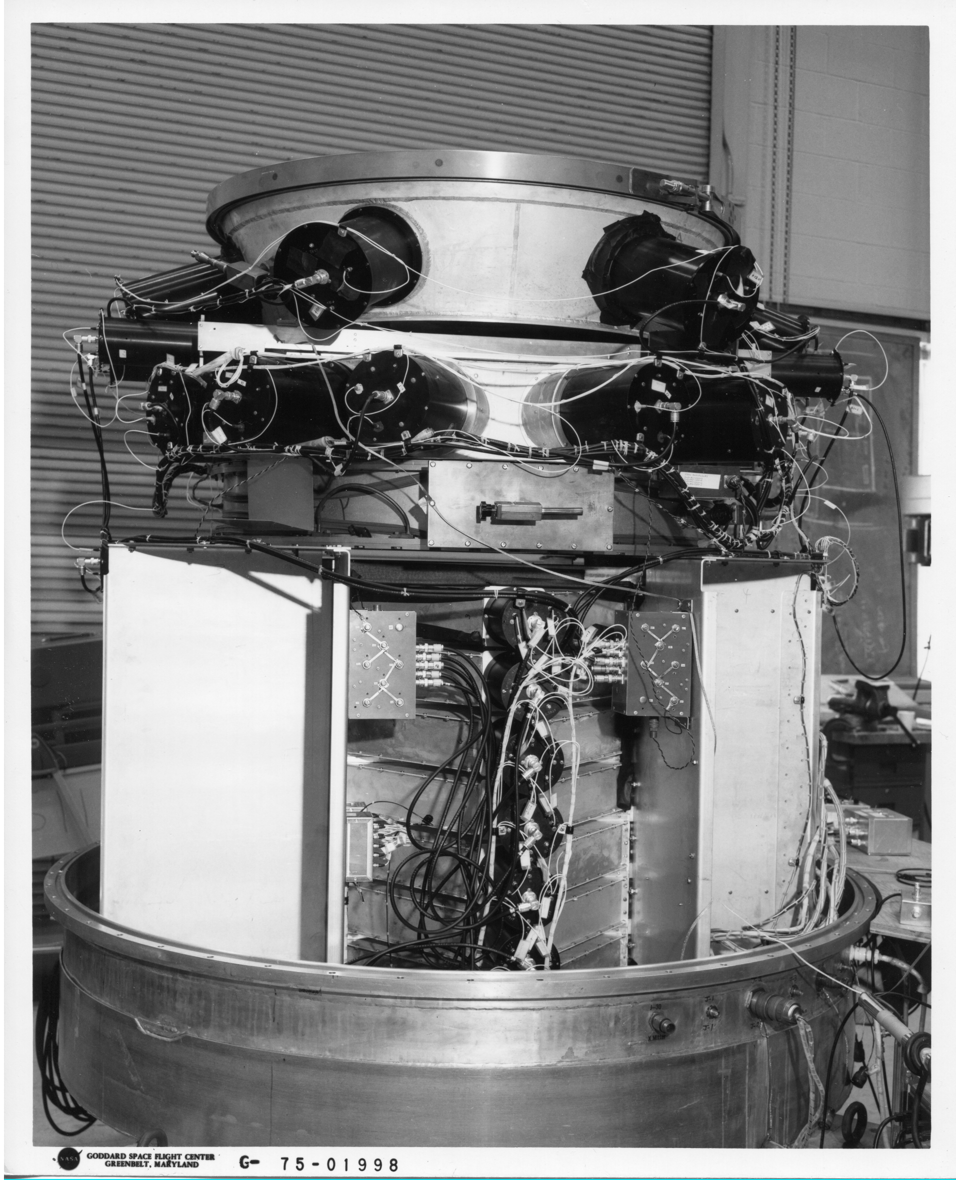
An experimental NASA apparatus, decorated with a jack-o'-lantern face and weighing nearly

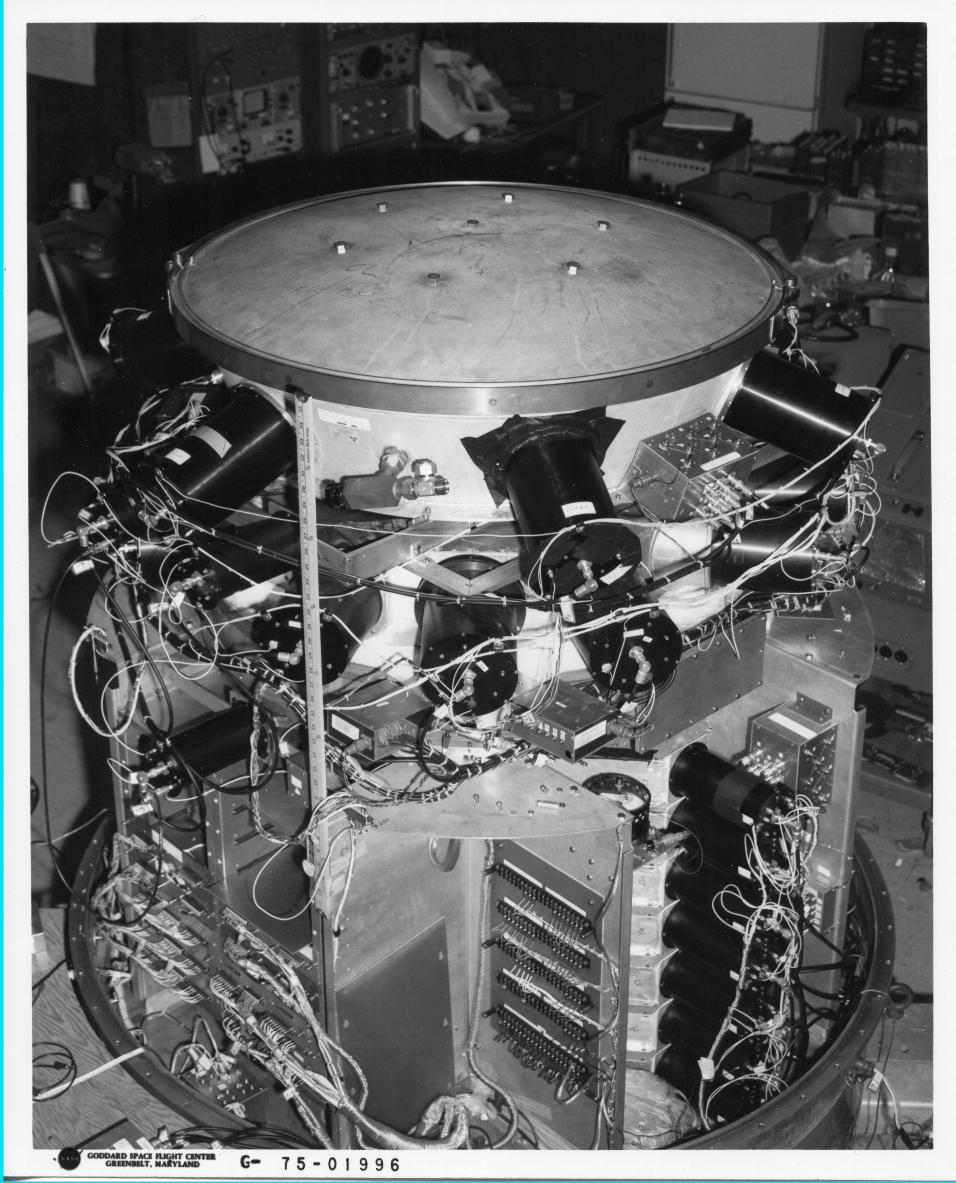
launched the apparatus Thursday, were called to the scene to recover an instrument box.

is sent to the area where the equipment is expected to fall.

Eight-year-old Greg Lane said he

This payload dropped into someone's back yard shortly after dark.


GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND
G- 75-01998


GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND
G- 75-01996

By this time, our gondolas had grown too expensive, big and heavy and it was no longer practical to fly them on balloons as we were building them.

Cosmic study planned

Staff Photo by Robert White

GODDARD-MARYLAND U. CALORIMETER
Righter, Streitmatter with 8,500-pound payload.

A huge aluminum ball covered with insulating material has arrived at the National Scientific Balloon Facility to be groomed for its first flight.

The spherical pressure dome, an energy-measuring device, is called a Calorimeter. It is the joint product of scientists at Goddard Space Flight Center, Greenbelt, Maryland, and the University of Maryland, College Park, Md.

Dr. Robert Streitmatter from the University of Maryland and Don Righter from Goddard SFC, are the scientists here to test the nine and one-half foot diameter instrument.

Other scientists involved in the project include Dr. John Ormes and Dr. V.K. Balasubrahmanyan of Goddard, and Dr. G.B. Yodh, Dr. Robert Ellsworth, Dr. Jordan Goodman and Dr. Palihalli Vishwanath of the University of Maryland.

Their payload will weigh 4¼ tons.

The Calorimeter is designed to measure cosmic ray energy within the high-energy band range of Tev, which is equivalent to a million million electron volts.

Dr. Streitmatter said 13 electron volts are required to pull a hydrogen atom apart.

The spherical pressure dome, to be flown under normal air pressure, is battery-powered. It is designed to measure the energy spectrum of cosmic ray protons and helium.

"If successful, it will measure at approximately to energies 10 times higher than has been done before by direct measurement," Streitmatter explained. He described that hoped-for attainment as evolutionary rather than revolutionary, another step up the ladder in that research field.

Tandem balloons—one above the other—will be used to lift the heavy payload.

The bottom balloon will have 6.7 million cubic feet capacity; the top balloon .47 of a million cubic feet capacity.

"We're here for tests and calibration of the instrument," Dr. Streitmatter said.

NASA G-77-06022

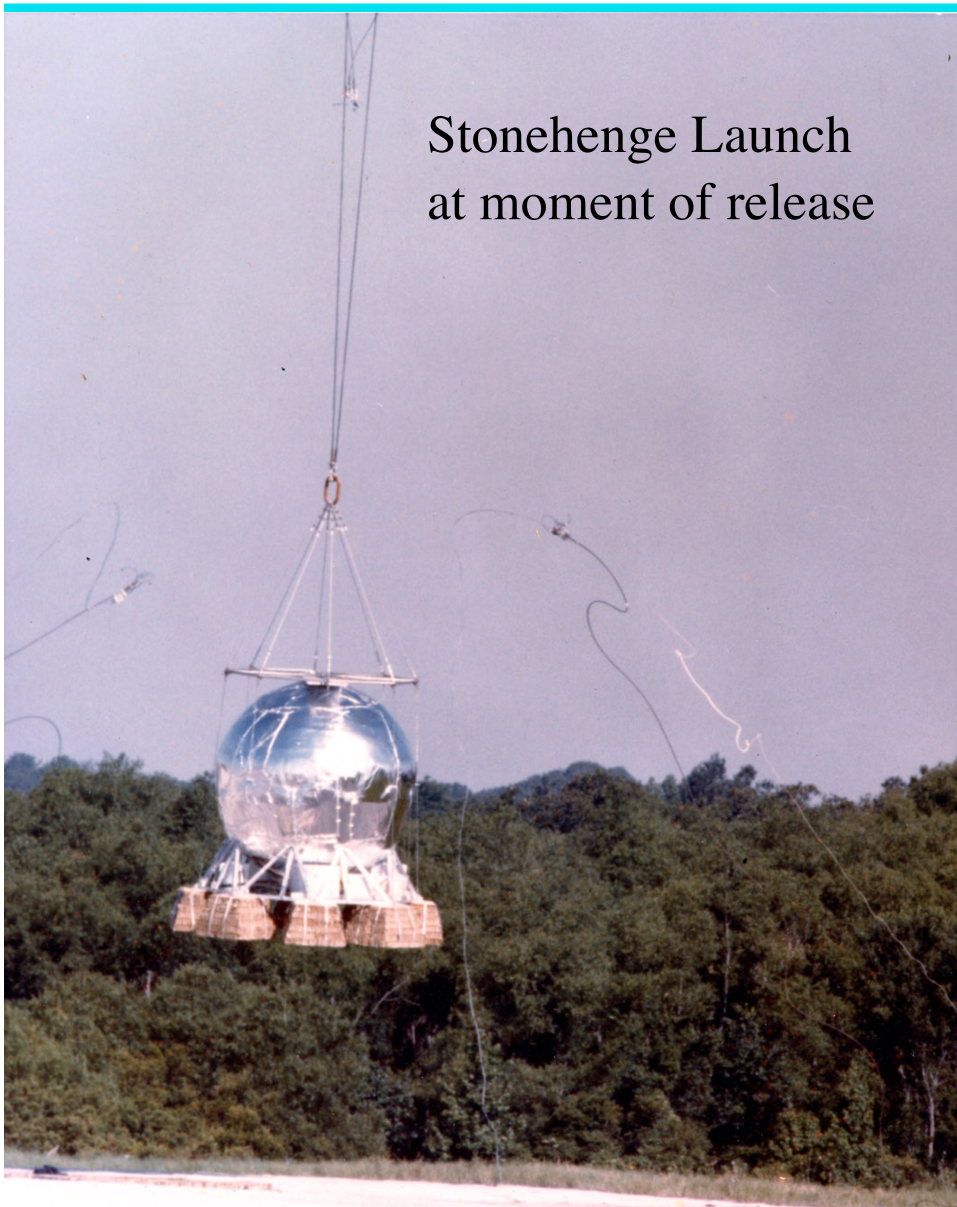
GUMPHS

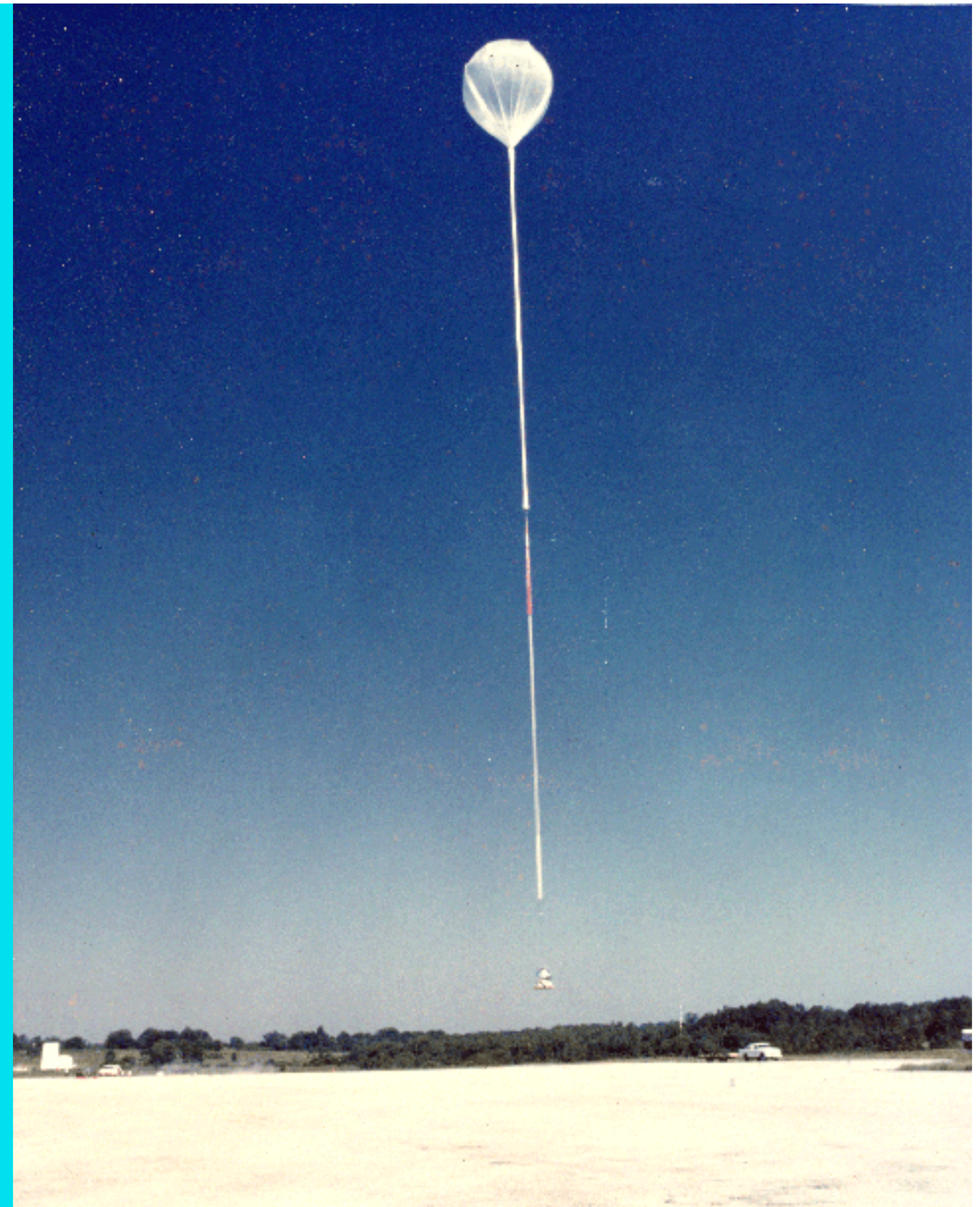
Launch

1978

Palestine, TX

The payload is ready


Stonehenge Launch
at moment of release



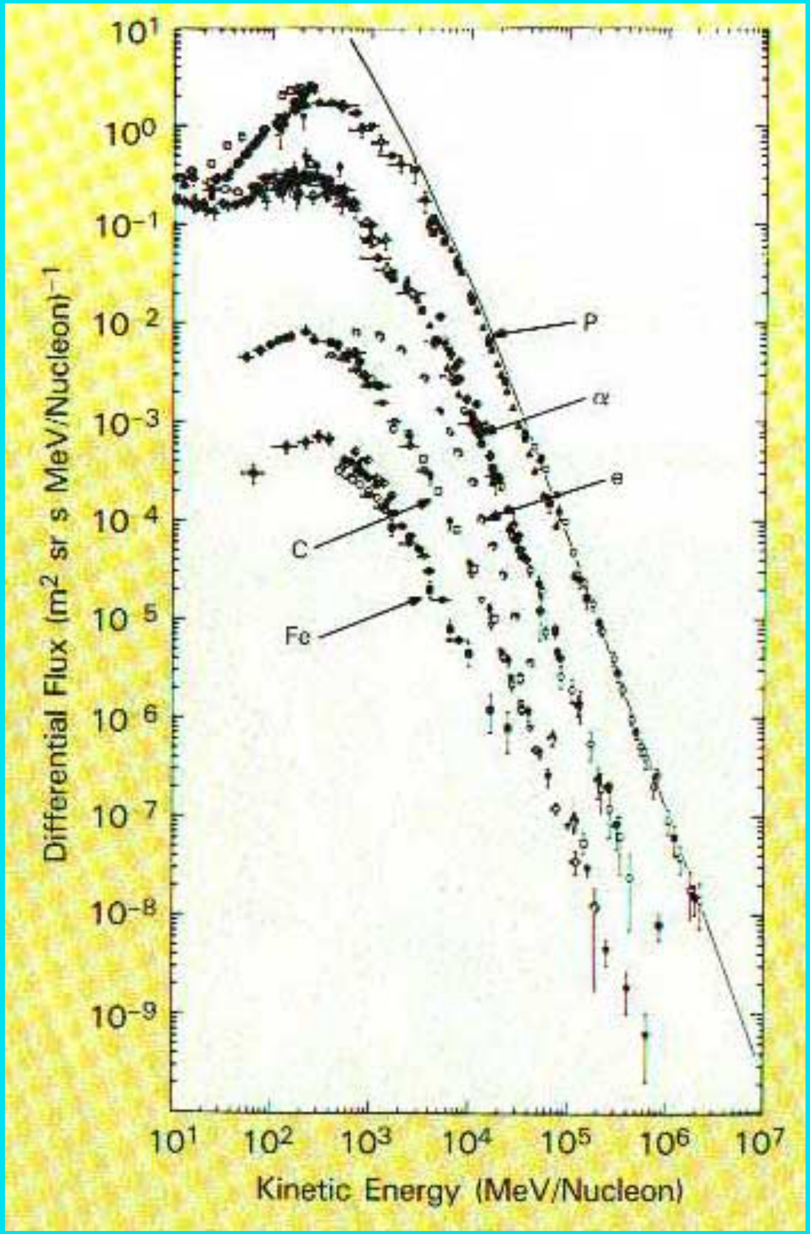
What are Cosmic Rays?

Nuclei from across the Galaxy and perhaps beyond

- **85% protons**
- **14% He nuclei**
- **1% heavy nuclei**
- **1% electrons**

Streaming at Relativistic Speeds

"A Thin Cosmic Rain"



All these experiments have taught us that the spectra of the different nuclei are essentially the same, implying they must all come from a common source.

We knew from the depth of the fog between us and their sources how long on average they lived in the galaxy (7×10^6 years).

From this we could estimate the amount of energy required to keep the galaxy filled with cosmic rays. Because the requirement was so large, people thought cosmic rays must somehow come from the explosions of stars as supernova. This was the only source of energy in the galaxy thought to be large enough.

Name	Common notation	Math notation	Exponent	Prefix
Googolplex		$10^{googol}=(10^{10})^{100}$		
Googol		10^{100}	100	
Nonillion	1000000000000000000000000000000	10^{30}	30	
Octillion	1000000000000000000000000000	10^{27}	27	
Septillion	1000000000000000000000000	10^{24}	24	Yotta (Y)
Sextillion	1000000000000000000000	10^{21}	21	Zetta (Z)
Quintillion	1000000000000000000	10^{18}	18	Exa (E)
Quadrillion	1000000000000000	10^{15}	15	Peta (P)
Trillion	1000000000000	10^{12}	12	Tera (T)
Billion	1000000000	10^{9}	9	Giga (G)
Million	1000000	10^{6}	6	Mega (M)
Thousand	1000	10^{3}	3	kilo (k)
Hundred	100	10^{2}	2	hecto (h)
Ten	10	10^{1}	1	Deca (da)
One	1	10^{0}	0	
One tenth	0.1	10^{-1}	-1	deci (d)
One hundredth	0.01	10^{-2}	-2	centi (c)
One thousandth	0.001	10^{-3}	-3	milli (m)
One millionth	0.000001	10^{-6}	-6	micro (m)
One billionth	0.000000001	10^{-9}	-9	nano (n)
One trillionth	0.00000000001	10^{-12}	-12	pico (p)
One quadrillionth	0.00000000000001	10^{-15}	-15	femto (f)
One quintillionth	0.00000000000000001	10^{-18}	-18	atto (a)
One sextillionth	0.00000000000000000001	10^{-21}	-21	zepto (z)
One septillionth	0.00000000000000000000001	10^{-24}	-24	yocto (y)
One octillionth	0.00000000000000000000000001	10^{-27}	-27	xonta (x)
One nonillionth	0.00000000000000000000000000001	10^{-30}	-30	weco (w)

Remember this?
Big numbers.

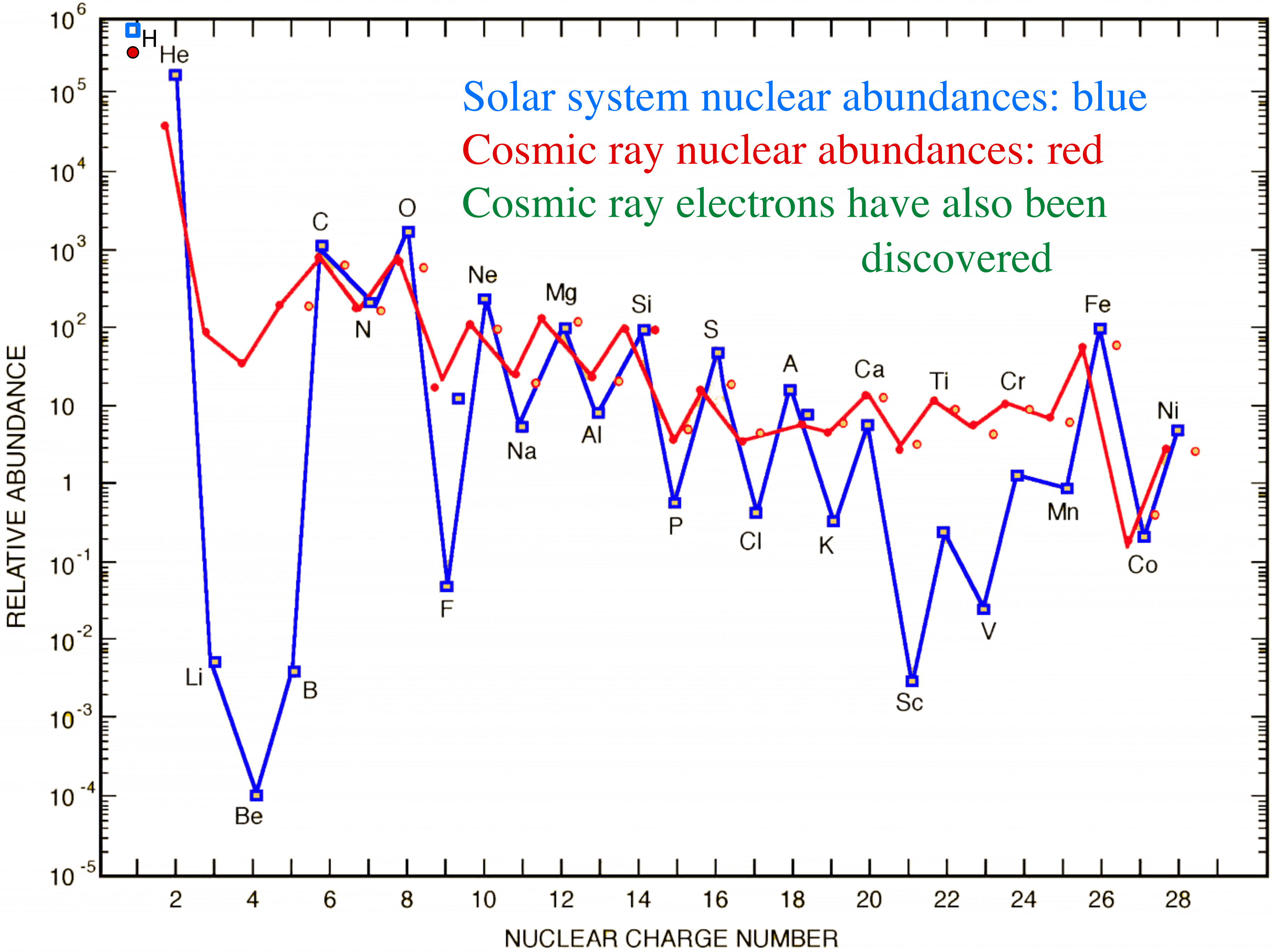
There appear to have been a supernova explosion of a star about once every 30-100 years in our galaxy (more on this later in the course).

A few percent of the more than 10^{44} Joules released in a typical supernova explosion must be converted to cosmic rays.

Conservatively, 3×10^{42} Joules/SN

300×10^{40} J/SN x 1/50 SN/yr = 6×10^{40} Joules/yr
2×10^{33} Joules/s = 2×10^{33} Watts =
2×10^{31} light bulbs shining 24/7

Sun puts out about 4×10^{26} Watts so it is **5 million suns**



Solar system nuclear abundances: blue

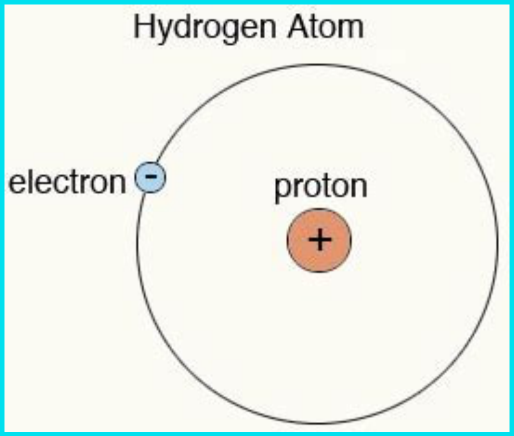
Cosmic ray nuclear abundances: red

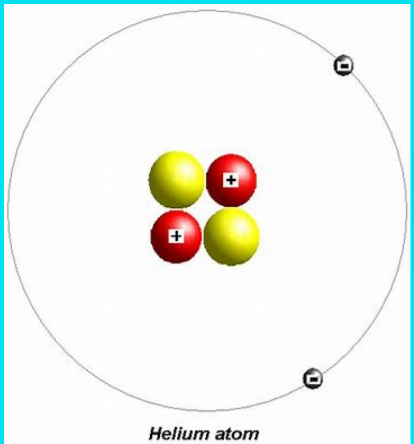
Cosmic ray electrons have also been discovered

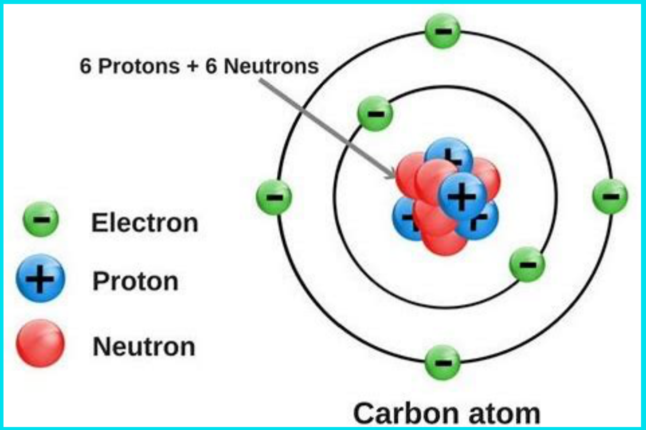
Let’s look in detail

- What happens to nuclei flying around the galaxy?

- How important are the electrons
  - 1-2% of the total incoming flux







1.1×10^{-10} m

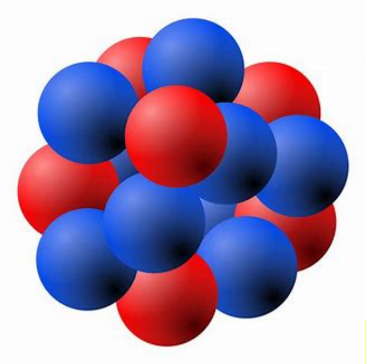
Z=1

1.0×10^{-10} m

Z=2

1.4×10^{-10} m

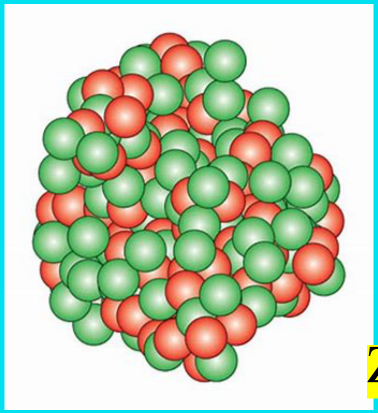
Remember this slide?



Z=6

Carbon nucleus

5.4×10^{-15} m

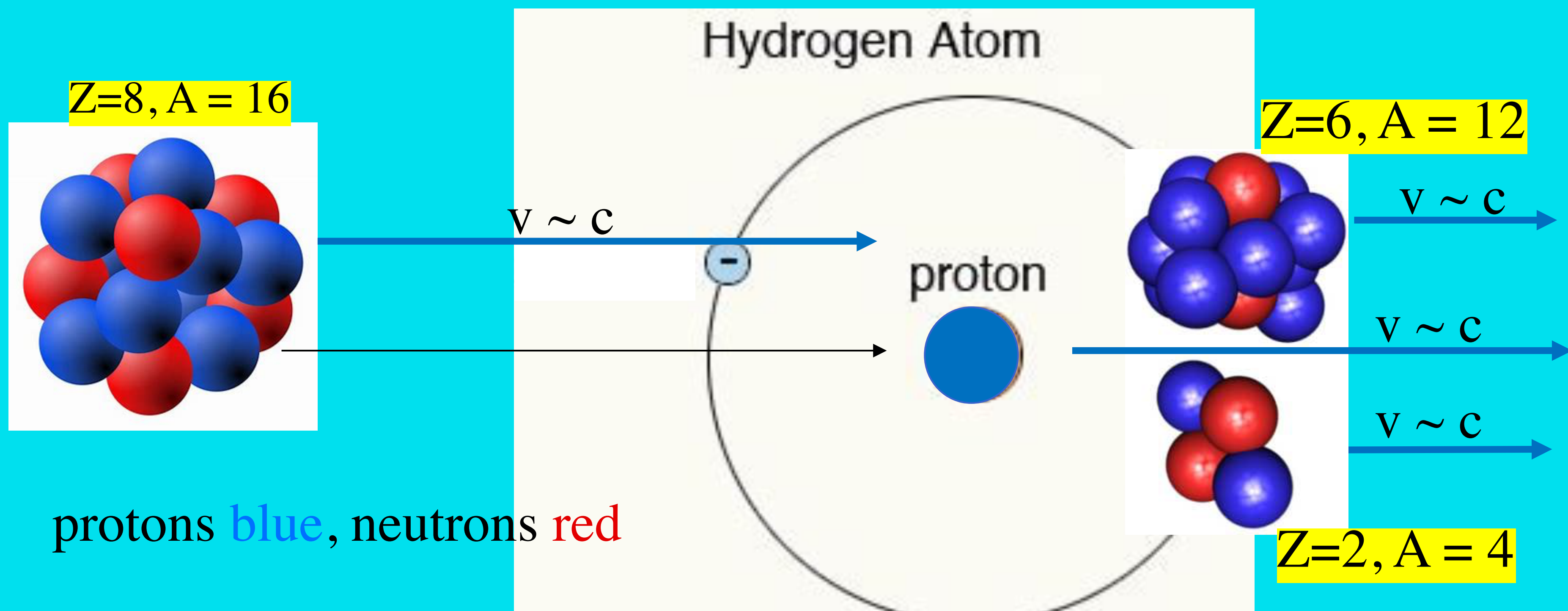


Z=92

Uranium nucleus

1.4×10^{-15} m

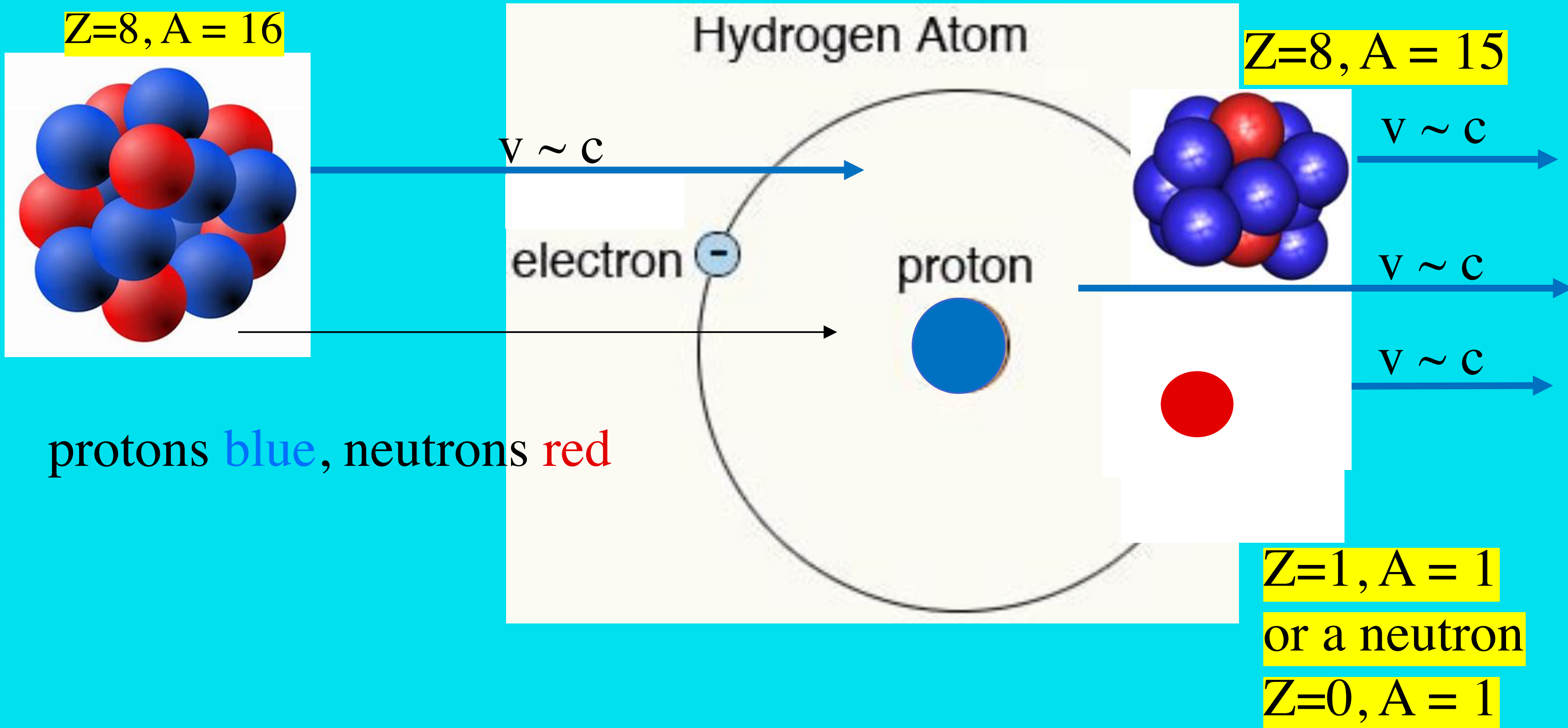
Let's represent the velocity of light by the symbol "c".
An oxygen nucleus travelling at almost the speed of light comes near a hydrogen atom in the gas in the interstellar medium.



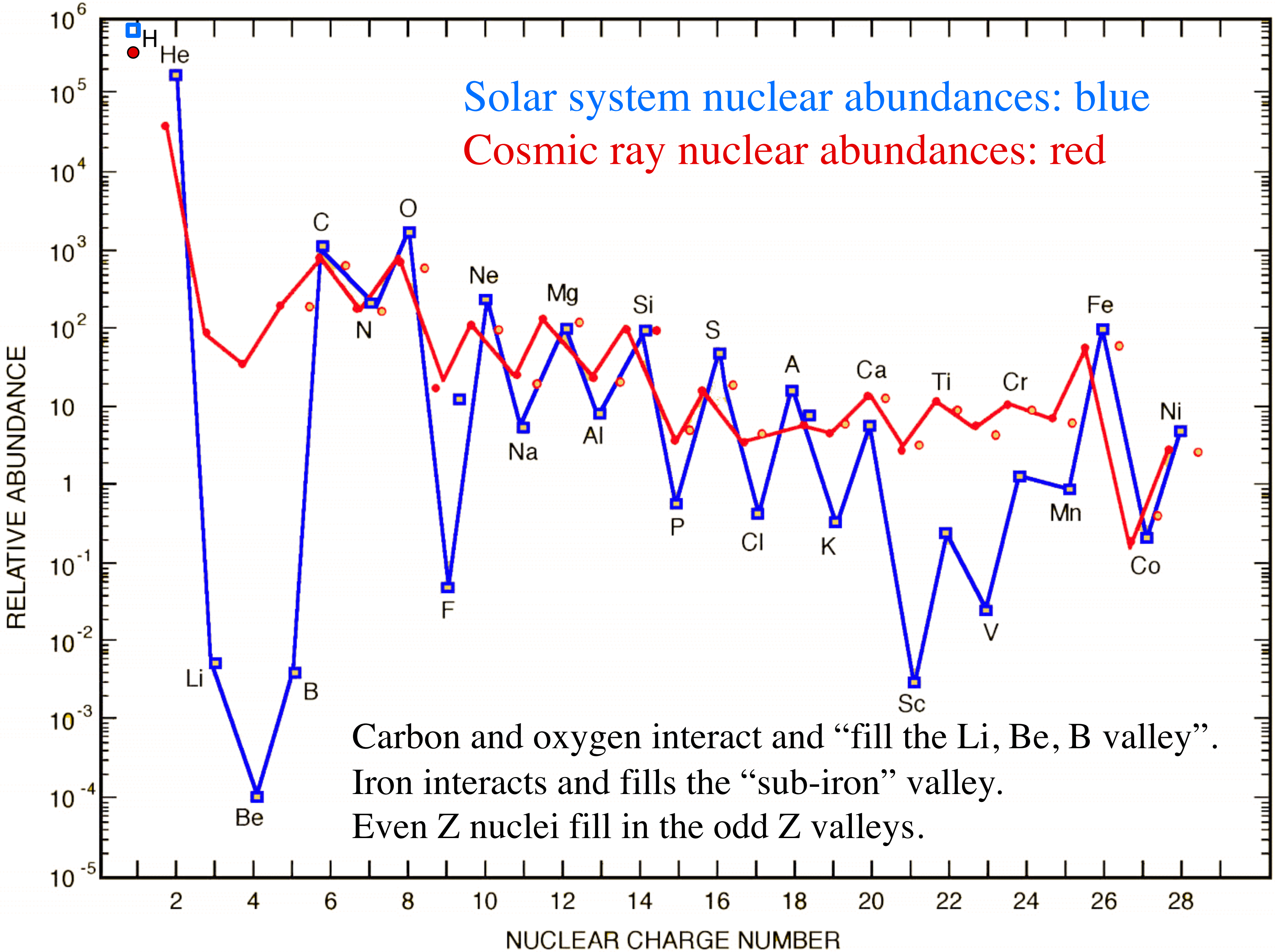
Lots of things can happen in the collision, depending on how close to "head on" the collision is. The various probabilities are measured independently at ground based accelerators and calculated theoretically. The collision often "knocks off" a helium nucleus leaving a lighter nucleus behind. In this case, it's a carbon nucleus.

Let's represent the velocity of light by the symbol "c".

An oxygen nucleus travelling at almost the speed of light comes near a hydrogen atom in the gas in the interstellar medium.



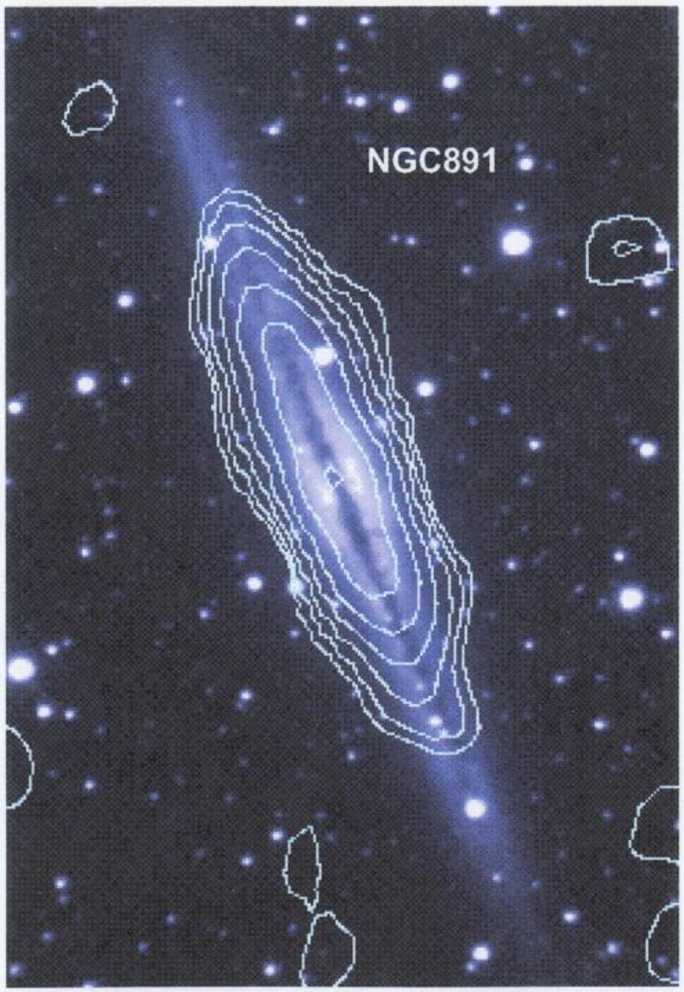
protons blue, neutrons red



Carbon and oxygen interact and "fill the Li, Be, B valley".
Iron interacts and fills the "sub-iron" valley.
Even Z nuclei fill in the odd Z valleys.

Enter some new evidence from radio astronomy

Optical image: Cheng et al. 1992, Brinkman et al. 1993
Radio contours: Condon et al. 1998 AJ **115**, 1693



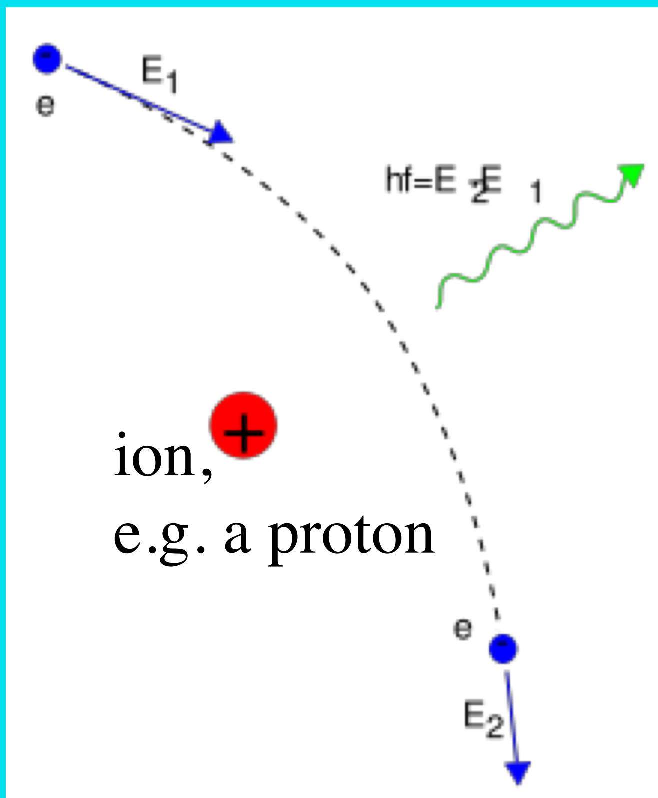
R Band image of NGC891
1.4 GHz continuum (NVSS), 1,2,...64 mJy/ beam

The image is of a galaxy similar to the Milky Way as seen edge on. It is like viewing the Milky Way from much further away.

Superimposed are radio emission contours. Think of these contours like the height lines on a contour map.

What is going on?

Protons and electrons: atoms and ions



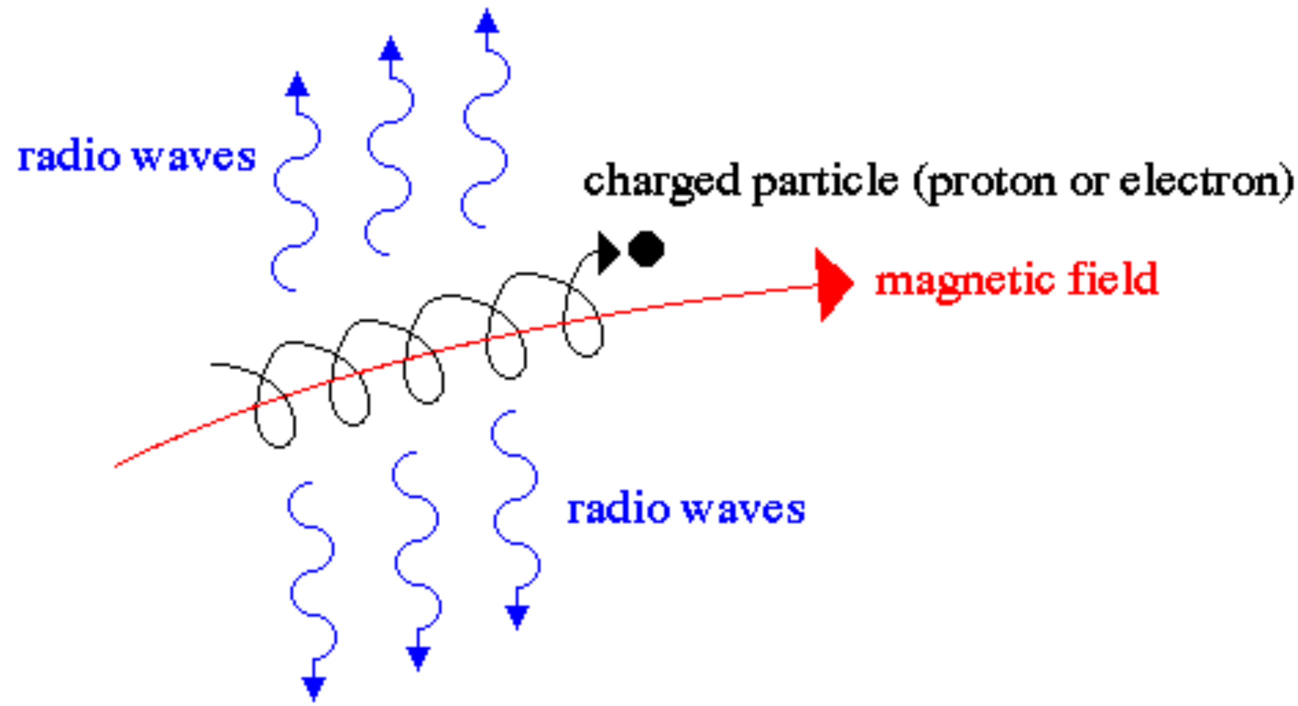
For ions, the electrons have more energy and are not under the control of the nucleus. We call these ions and electrons (free).

The electron experiences the electric force of the ion. Like charges repel, unlike charges attract, so the electron is bent towards the ion. The electron is accelerated (forced into a curved path) causing it to radiate the invisible green photon.

Any accelerated ion will lose energy

- Any particle that is forced to change its path from a straight line is subject to a force that causes it to lose energy.
  - Previous slide & next slide give examples
- In this next case, the energy lost appears in the form of radio waves.
- Radio emission from cosmic ray electrons spiraling in magnetic fields, which are ubiquitous in space.
  - By measuring the radiation we can find out the magnitude of the magnetic field
  - The interplanetary magnetic field is weak by terrestrial standards (10^{-9} Tesla) but it is important on the large distances in space.

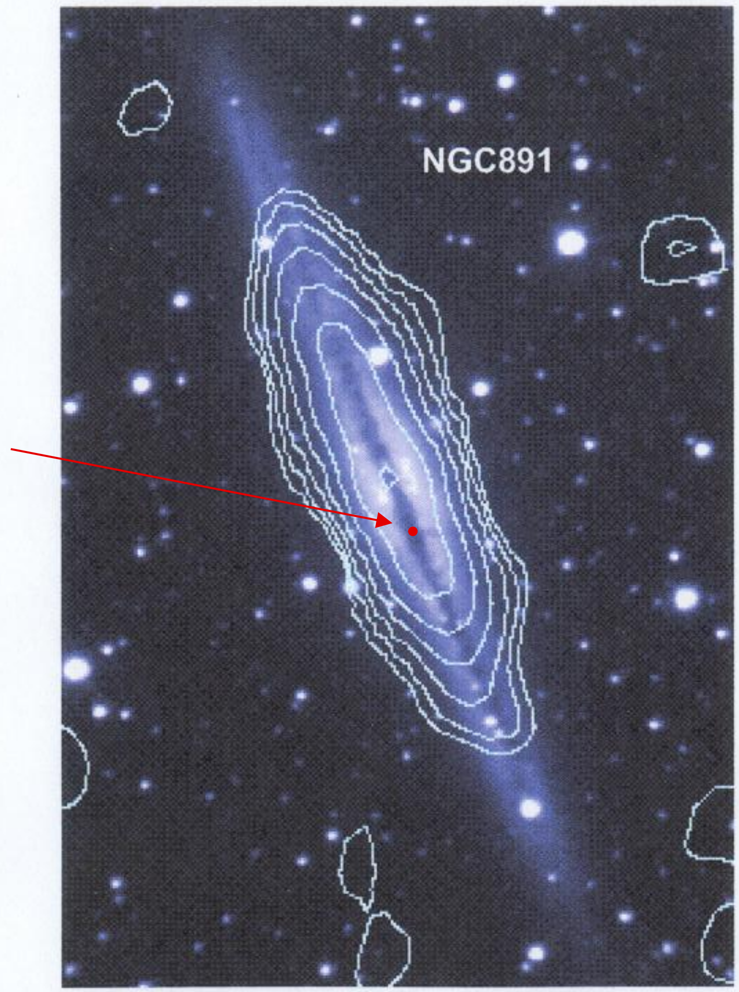
Synchrotron radiation



synchrontron radiation occurs when a charged particle encounters a strong magnetic field – the particle is accelerated along a spiral path following the magnetic field and emitting radio waves in the process – the result is a distinct radio signature that reveals the strength of the magnetic field

Enter some new evidence from radio astronomy

Optical image: Cheng et al. 1992, Brinkman et al. 1993
Radio contours: Condon et al. 1998 AJ **115**, 1693



R Band image of NGC891
1.4 GHz continuum (NVSS), 1,2,...64 mJy/ beam

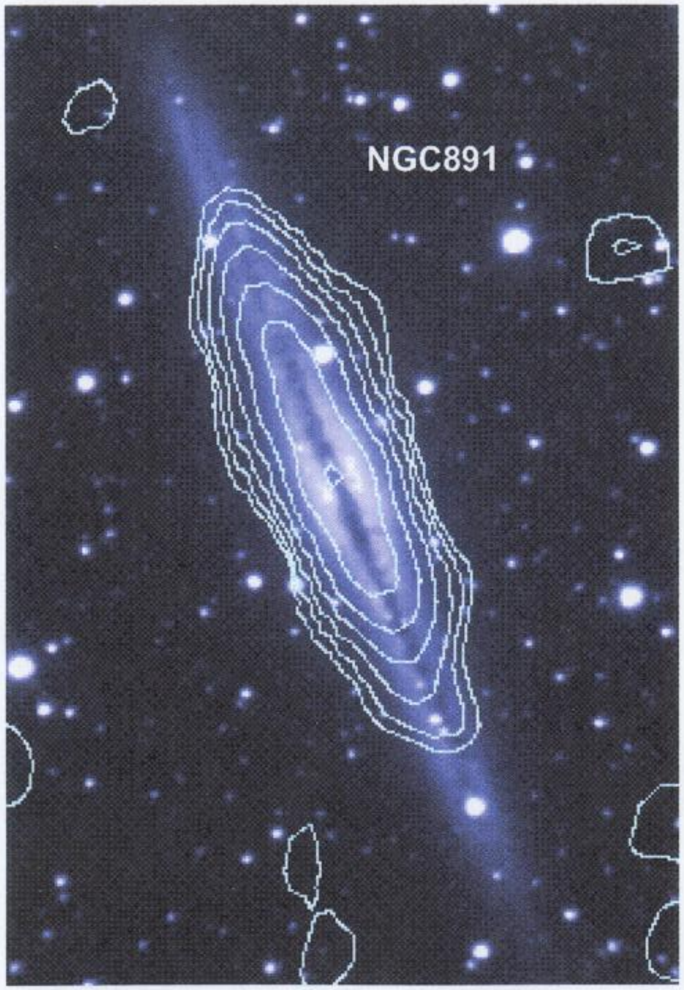
This is a contour of the electrons spiraling in the galactic magnetic fields giving off radio waves.

More emission is coming from the plane of the galaxy, but there is a large flat peak at the top.

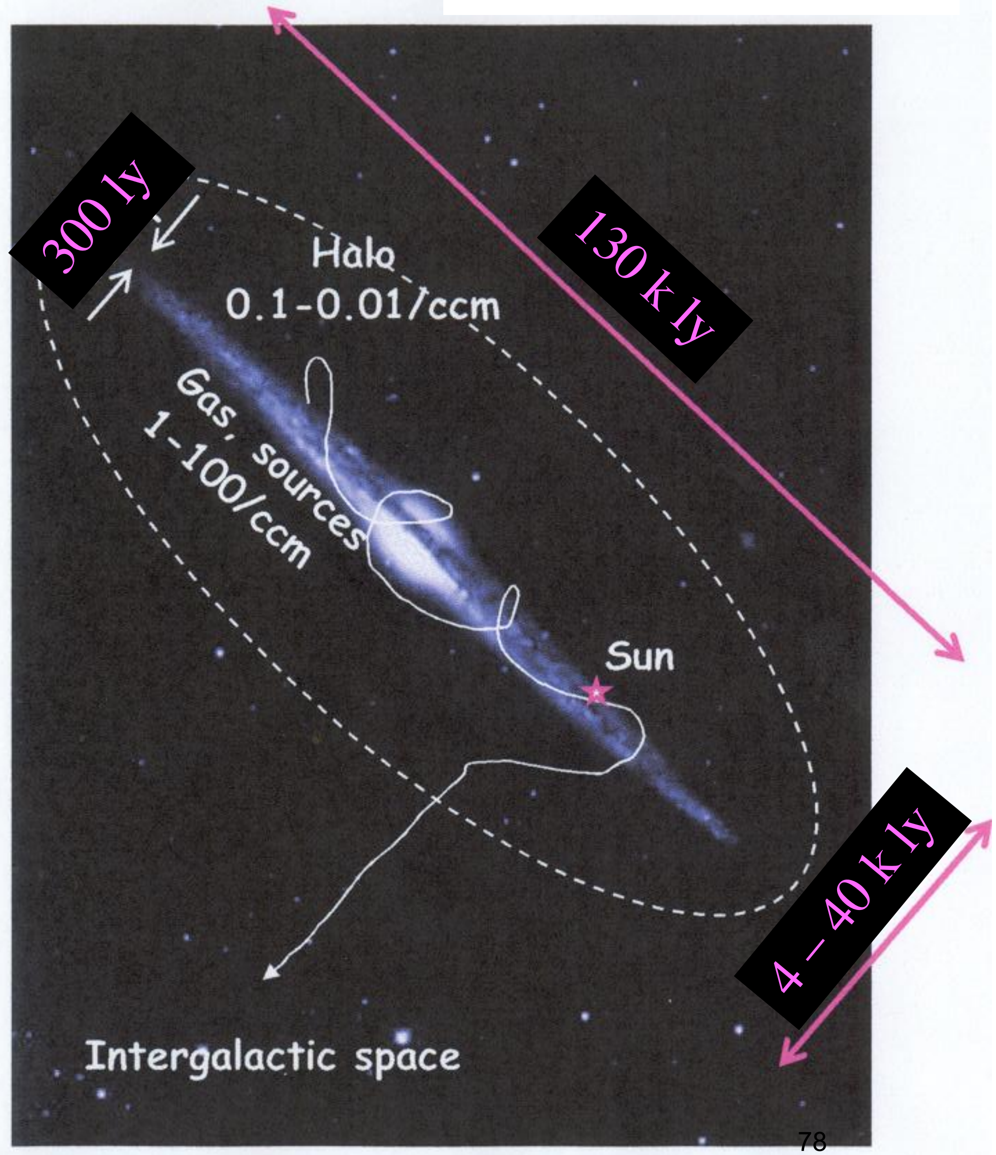
The red dot indicates where the solar system would be if this were the Milky Way.

Cosmic ray nuclei live in galaxies

Optical image: Cheng et al. 1992, Brinkman et al. 1993
Radio contours: Condon et al. 1998 AJ **115**, 1693



R Band image of NGC891
1.4 GHz continuum (NVSS), 1,2,…64 mJy/ beam



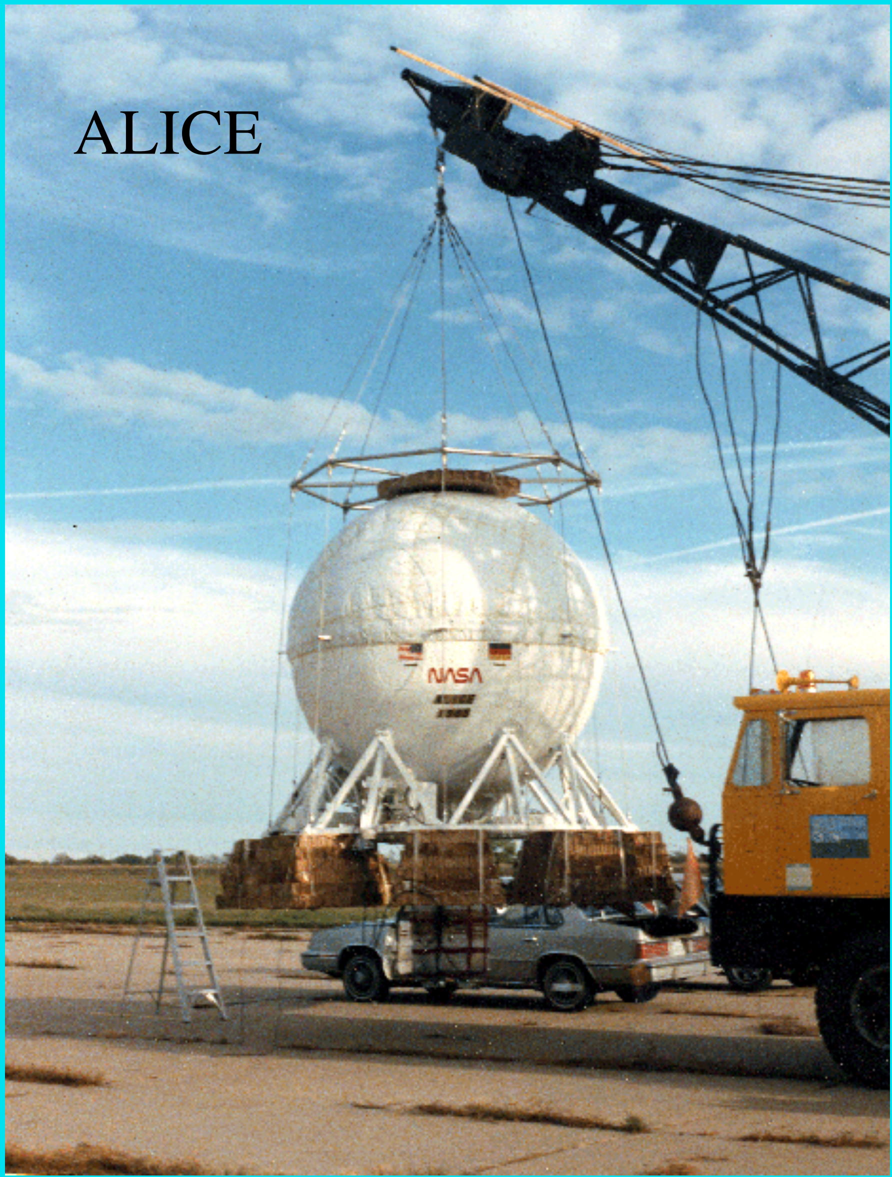
Theory of cosmic rays

- We are apparently seeing cosmic rays through the fog of their interactions as they traverse thegas and dust in the interstellar medium.
- As the primary cosmic rays, with an abundance distribution like that of solar system material, interact with interstellar gas and dust, they fill the abundance valleys of the cosmic ray distribution.
- Once we correct for this fog, we get an abundance distribution very much like that of solar system material as determined from measurements of solar spectra and meteorites.
- Conclusion: cosmic rays come from the same place all our nuclei come from.

When we correct for the changes in composition for the journey from the sources (what are they) to Earth, it is very similar to solar system abundances.

Let's see if the isotopic compositions follow suit.

We named her ALICE, A Large Isotopic Composition Experiment.



Isotope Experiment: we found non-solar abundance of $^{22}Ne/^{20}Ne$ and other isotopes in an unsophisticated balloon borne experiment.