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Introduction to Astrophysics and Study of Cosmic-ray Collisions and Scanning

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Physics H492

Introduction to astrophysics and study of Cosmic-ray collisions and scanning.

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Presented
to
Dr. J. Fatrick.

#168

Presented
by
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Contents

Atomic Energy and the Sun

The discovery of tremendous amounts of energy from the Atomic Explosion (Ex. first Atomic Bomb on Hiroshima) was not something new. For billions of years, atoms have been splitting with the release of such energy whenever stars are shining. We know that the atomic energy is being released from the sun and stars, and that this process has been going on for unthinkable years. However, the sun's atomic energy has been under control constantly, and its release of radiation (dynamic force) has supplied the constant supply of light and heat best suited for the well-being of mankind.

There are times, however, when apparently accidents can happen even in the solar laboratories; for explosions do occur on the sun that effects ~~on~~ the earth out in a safety zone of space 93 million miles away from the Sun. On such occasions, we can say that in a fairly true sense an "atomic bomb" has exploded on the sun. These solar explosions occur most frequently when the sun shows on its otherwise uniformly bright surface dark blotches familiarly known as "sunspots".

Sun Spots (a)

They are fundamentally described as due to atmospheric disturbances in the surface layers of the Sun. However, the periodic nature of the recurrences of sunspots has suggested to some that the planets in some way had become the disturbing bodies. But, it has led the astronomers to believe that the fundamental cause of sunspots is to be found entirely within the sun itself, rather than the belief about sunspot activities on the basis of planetary cycles.

Many astronomers believe that the origin of sunspots is associated with the heating and cooling of the gases within the solar sphere incline to the idea that irregularities in the "period" are inevitable, and that it is probably useless to attempt predicting variations from it.

In connection with the origin of sunspots, it is most important to remember that the Sun rotates more rapidly near the Equator than near the Poles. The consequence of this, there must be a continuous slipping between the atmospheric gases in the lower zones against those circulating less rapidly in the higher latitude zones.

On the other hand, many scientists who have attacked the problem of the origin of sunspots have believed that outside forces acting on the sun are primarily the cause of sunspots. Suppose the planets circulating about the sun are considered as "possible" sources of disturbances in the sun, then we may well consider to just what extent that the planets could be expected to produce any effect upon the gases in the sun.

The raising of tidal waves on the sun by the planets would tend to set the whole solar atmosphere into "oscillation". As the sun rotates, it carries the atmospheric particles past the point of major attraction, successive pulses would cause the increase of the amplitude (of the waves) as the period of oscillation of the atmosphere was comparable with the intervals between successive pulses. In this way, it is possible that even the slight tide-raising forces of the planets could, in the course of time setting up a major oscillation in the sun's atmosphere. Thus, it may be very much the way in which synchronized footsteps of a regiment may set away a bridge.

However, we must not neglect that the factors of analyzing the periods of planetary motion, plus the natural periods of oscillation of the solar atmosphere, may bring some progress on the prediction of sunspots from planetary effects.

If we suppose, then, that it is in these zones of latitude either side of the solar equator that the oscillatory disturbances are started, there might be a general movement of the particles in the solar atmosphere from these zones toward the equator in either atmosphere, just as there is a tendency due to the tides of the ocean for the water from 45° latitude to flow toward the equator, the region that, on the average, is most nearly under the moon.

As the disturbances start in these zones on the sun and move toward the equator, vertical whirls would gradually be generated as the cross current meets the region of the sun's atmosphere that is moving rapidly westward. These eddies would break out as "sunspots" in latitudes lower than the 45° zone. These would be in general agreement with the latitude of the first sunspot breaking out in new cycles. The oscillatory motion of the solar atmosphere would gradually be damped out by the lack of complete conformity between the intervals of the pulses of the planetary tidal forces and the natural period of oscillation of the sun's atmosphere. The spots, therefore, might be expected to peter out at the equator at the end of this interval. By the time of disappearance of this series of oscillations, the continued pulses would start a new cycle at high latitudes, thus ushering in the new sunspot period.

The fact that the atmosphere of the sun in which the sunspots occur may be a thousand times more tenuous than that of the earth's atmosphere favors a natural period of oscillation of at least several days. Furthermore, the effect of the gravitational attraction of the sun upon the particles in its atmosphere is very considerably minimized by the outward pressure of radiation coming from the interior of the sun. This is another reason for believing there may be natural periods of oscillations of relatively long duration.

From time to time various investigators have resorted to some sort of electrical hypothesis to account for the origin of sunspots. Such an hypothesis presumes that electrical charges exist on the sun, and that the various planets are at different potentials. Since both gravitational attraction and electrical attraction follow the inverse-square law, any small electrical effects which might exist between the planets and the sun might well be obscured in the gravitational constant which astronomers have long derived from the well-established equations of celestial mechanics.

Sun Spots (b)

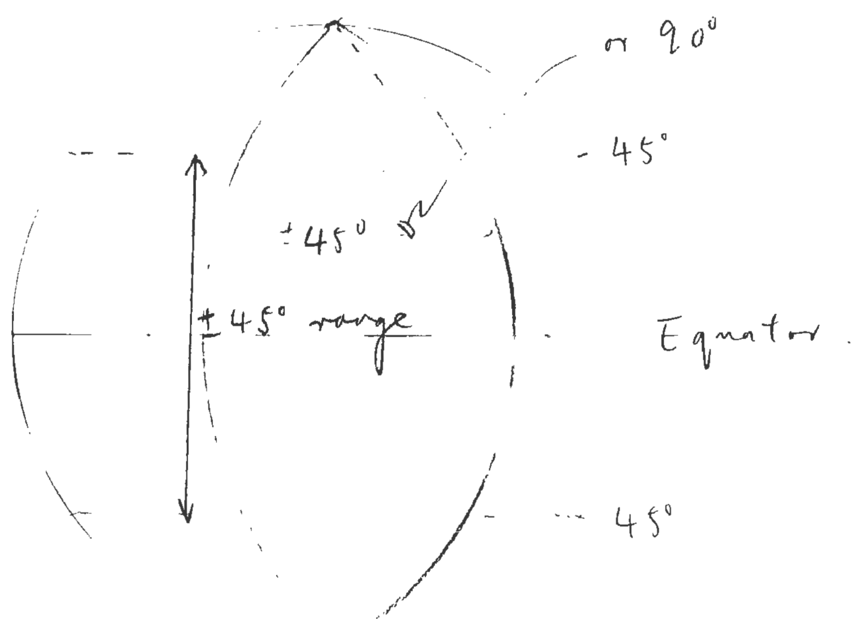
Sunspots are dark markings on the Sun composed of a dark center called the "umbra" and a border region called the "penumbra". The umbra is rather structureless, but granulation has been found in it. With good seeing conditions, the penumbra is found to consist of a group of small filaments radially oriented with respect to the center of the umbra. The ratio of the diameter of the penumbra dp (diameter of the penumbra) to the diameter of the umbra du (diameter of the umbra) is somewhat independent of spot size and has the value of $dp / du \doteq 2.4$. This value is lower for large spots. Some well-developed spots show a bright ring around the penumbra some 2 to 3 per cent brighter than the photosphere. The diameter of a sunspot ranges from several thousand kilometers. A large spot group can attain lengths of over 100,000 Km. The shape of the upper boundary of sunspots can be inferred from direct observations, and it is concluded that the upper surface is actually a shallow, depressed area.

The formation of a spot group begins with the appearance of a small spot or "pore" between the granules. Ordinarily, the appearance of one pore is associated with the appearance of another, nearby pore, and a young spot develops. This young spot group may disappear after a few hours, or it may develop into a large group.

The location of sunspots on the solar disk is variable. Mostly all sunspots are found in two zones some 15° to 20° wide, parallel to

the equation, and within ±45° latitude*.
The position of the sunspot zone varies through the solar cycle.
It should be emphasized that only the locality of appearance varies throughout the cycle; the spots themselves have no appreciable motion in latitude during their lifetime of about one month.

*



Sun Spot (c)

Part of the surface has lost ~~the~~ temperature (i.e. below 6000°K), As that particular part, compared with the rest, has cooler surfaces. Thus, the contrast of temperature shows off a dark spot. And, it becomes exothermic, viz. energy is released and giving out (i.e. travels as Solar Wind). See the sketch in P. the Magnetic Storm.

The Hypothesis of some High-energy Particles or Radiation.

The study of cosmic rays was born when C. T. R. Wilson and also Elster and Geitel found a small unaccountable leakage of charge in an electroscope which had been carefully insulated. The cause was not due to insulation but due to ions formed by penetrating radiation.

At first, it was supposed that the radiation came from radioactive material distributed throughout the earth's surface. However, the amount of shielding which could cut off radioactive substances failed to cut off the unknown penetrating radiation.

In 1910, Gockel in Germany ascended to an elevation of 14,000 feet in a balloon and found to his surprise that the intensity of the radiation did not decrease with elevation, as would be expected if the rays came from the earth, but increased instead.

Discovery of the Radiation

In 1911, Hess (in Austria) and Kohlhorster (in Germany) took electroscopes up in balloons to much higher altitudes and found the intensity of the unknown rays to be as much as ten times that at the surface of the earth. Hess called it "high-altitude radiation". Later, Hess' results were confirmed over and over again. He proposed that the rays originated from somewhere outside the Earth's atmosphere (space). Robert Millikan named it "cosmic rays".

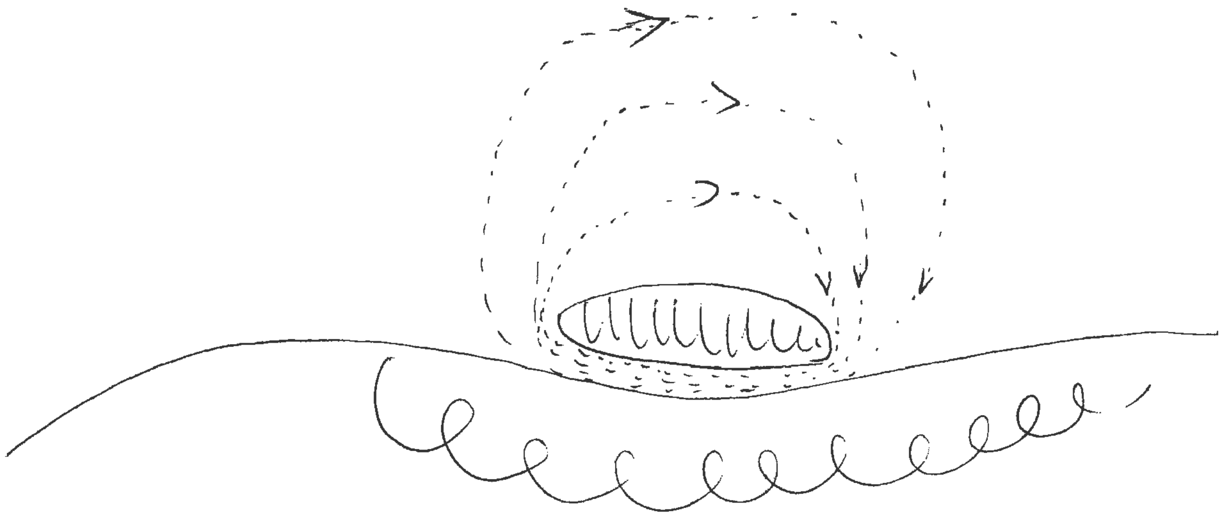
In 1936, Hess was awarded with the Nobel Prize for the "Discovery of Cosmic Rays"

Sources of Cosmic Rays

Investigations of different parts of the sky with a "cosmic-ray telescope" give no indication of a favored source for cosmic rays. They seem to come equally from all directions in space. It seems fairly certain that large numbers of the "lower-energy particles", which we speak of as cosmic rays, have their source in the sun and are scattered throughout the solar system by means of the magnetic fields of the sun, the earth, and some of the other planets in such a way that they seem to come uniformly from all directions of space.

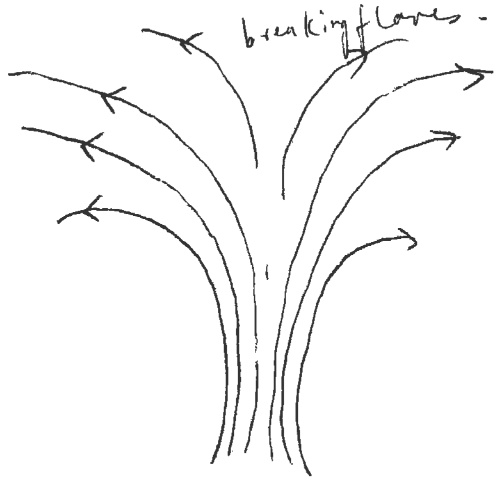
In times of sunspot activity and solar flares, streams of charged particles are shot off from the sun and may reach the earth (the movement of reaching is like "solar wind"), producing "magnetic storms" when sufficiently intense.

Brief Sketch of Solar Activity or the Formation of Magnetic Storms



Sunspot (magnetic storm)

Charged particles follow when they get up to a certain climax



Solar flare

Cosmic rays come out when flare breaks.

The production of the higher-energy particles, however, is far more difficult to explain and no satisfactory theory seems possible in terms of any mechanism connected with the sun. Indeed it is difficult to think of any kind of mechanism anywhere that could produce the small number of highest-energy particles a very few of which have energies estimated as high as 10^{17} eV although probably only only 10% have energies above 20 meV.

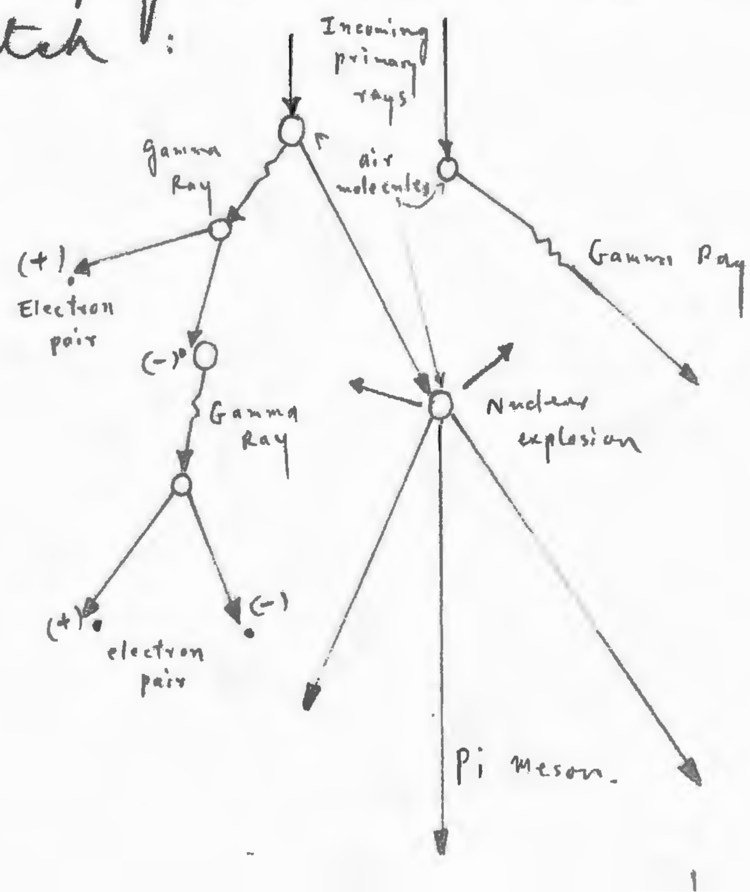
A suggested source of high-energy cosmic rays is the type of star known as a "nova" or "supernova". In the apparent atomic explosion of such a star, it seems that particles of very high energy might be produced if the "nova" were surrounded by a time-charging magnetic field enabling it to act as a huge particle accelerator. However, the occurrence of those novae is comparatively rare. Certain pulsating stars may have pulsating magnetic fields and might also act as giant accelerators to speed up such particles.

If there are floating clouds of ionized gas (plasmoids) in "interstellar space", repeated collision of charged atomic particles with these clouds over periods of millions of years could conceivably build up high energies. More recently it has been suggested by Hoyle that Cosmic Rays production may be connected with the formation of the unusually massive stellar objects (far more massive than a single star!) whose existence seems to be indicated by radio astronomy.

Secondary Cosmic Rays.

All rays produced in the atmosphere by action of a primary cosmic ray are called secondary rays. Secondary rays are produced by a variety of processes, and they may include a number of different types of rays. Measurements of secondary rays indicate that there are present in the atmosphere high-speed electrons, positrons, mesons, high-energy gamma rays, and even neutrons, together with many other particles not so well known. The two chief types of event by which secondary rays are produced in our atmosphere when high-energy primary rays collide with air nuclei (mainly oxygen and nitrogen) are "Cascade showers", and the disruption of nuclei which give off showers of "mesons" or other particles. Since mesons decay rapidly they cannot be primary particles but must be produced high in our atmosphere.

In a cascade shower there are three chief kinds of event: (1) production of gamma-ray photons when an incoming primary ray is suddenly slowed down in an encounter with a gas molecule, (2) creation of an electron pair by a gamma-ray photon in the presence of some other nucleus (in order to conserve momentum); and (3) further production of gamma-ray photons by slowing down of these electrons in collisions or nuclear encounters. As this process proceeds and repeats itself, gamma rays, electrons, and positrons multiply as indicated in the following sketch:



The very penetrating particles in the cosmic rays which reach the surface of the earth in abundance are "Mu Mesons" (When the Pi Meson undergoes radio-active decay and formed a Mu Meson) They are particularly penetrating because they do not interact directly with atomic nuclei. At the surface of the earth more than half the cosmic radiation consists of mu mesons, the remainder consisting chiefly of the electrons, positrons and gamma ray photons produced in cascade showers.

Cosmic Rays in the Solar System, in the galaxy, and beyond.

The intensity of energy reaching the earth in the form of cosmic rays is nearly the same from all stars (in the form of light), except from the sun. The comparison of energy-receiving is rather ~~~~ difficult to answer. The problem is more complicated in the case of cosmic rays than in the case of star light, because light travels in straight lines and cosmic-rays particles (electrically charged), are deflected (or affected) by magnetic fields (the earth itself has many magnetic fields). Magnetic fields may retard the escape of cosmic-ray particles from the regions of space in which they are produced, and thus cause local ~~concentrations~~ variations in the particle concentration (as described ~~for~~ the Van Allen Radiation Belt).

If there are effective fields in the Solar System, a small supply of high-energy particles from the sun would suffice to maintain the observed flux of cosmic rays. Furthermore, cosmic rays would bounce back and forth before reaching to the earth. that may indicate they come from all directions, rather than only from the sun. Then, the sun, and presumably other stars as well, would be surrounded by an "atmosphere" of cosmic rays, whereas the cosmic ray flux in interstellar space may be negligible.

Stars and interstellar matter are not distributed uniformly throughout the universe but are condensed in galaxies. If we assume the cosmic rays are produced in galaxies rather than in the nearly empty space between galaxies, then most of the observed radiation should come from our own galaxy (about 10^{11} stars). Other galaxies, because of their great distance, should not contribute more than a small fraction of the cosmic-ray flux, just as they do not contribute more than a small fraction of the light flux in the night sky.

The Solar System is located near the median plane of the galaxy, about two-thirds of the way from the center. The distribution of galactic stars and galactic interstellar matter with respect to the earth is therefore very uneven. (this ~~may~~ explains the Milky Way appearance). Presumably, the sources of cosmic rays are also distributed very unevenly. If there were no magnetic fields in the galaxy, the intensity of cosmic radiation reaching the earth from different directions would vary. Thus, if cosmic rays are of galactic origin, there must be magnetic fields in the galaxy capable of producing a random distribution of cosmic radiation in space. It is quite likely that magnetic fields keep cosmic-ray particles trapped in the galactic volume for long periods of time (when compared to the time required to escape along straight lines). Our galaxy, as well as other galaxies (having their own cosmic-ray populations), while in the space between galaxies, the density of cosmic rays would be almost negligible. Thus, if this view is correct, even intermittent sources of cosmic rays within each galaxy (as discussed in the supernova) might maintain a fairly steady cosmic-ray flux.

Effect of Earth's Magnetic Field.

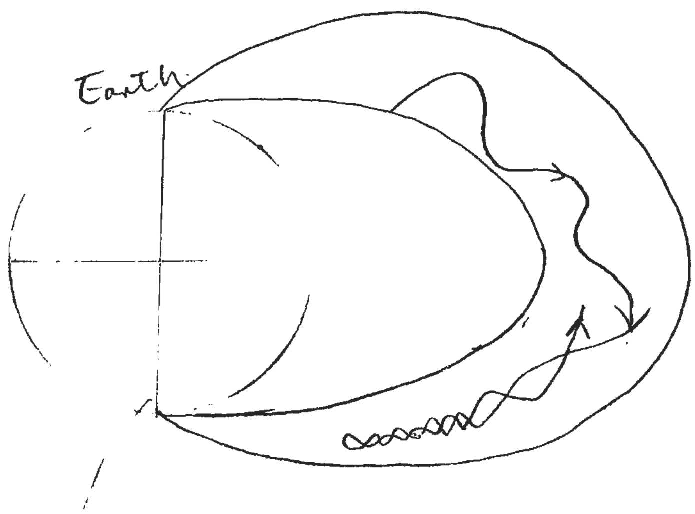
The phenomenon of variations of cosmic-ray intensity have been measured, tested on various regions (of different latitudes). And this is due to the earth's magnetic field.

At the magnetic poles, incoming charged particles can move freely along the magnetic field without deflection or worst, if moving at a slight angle to the field, they would follow a spiral path inward. But near the magnetic equator in-coming rays of a given electric charge, upon crossing the earth's magnetic field, would be bent away from the earth or toward the earth depending on the direction in which they were moving. Some of these bent away from the earth would, of course, miss it altogether. Those bent toward the earth, if possessing enough energy, would hit right at the target.

Consideration of the energies required by particles to enable them to reach the earth indicates that protons of approximately 60 billion electron-volts energy are bent in the equatorial plane of the earth, so that the radius of curvature of path is smaller than the earth's radius; therefore these protons can reach the earth regardless of direction in the equatorial plane. Such particles, with energies of less than 10 billion electron-volts, will not be able to reach the earth at all at the equator; those of 10 billion volts or a little more will arrive from a westerly direction if they are positively charged and from an easterly direction if they are negatively charged. If they have energies of 15 Bev or more, they can arrive at any angle between the western horizon and the zenith. At the poles particles of any energy can reach the surface of the earth except for losses such as those due to collision, radiation and ionization. These losses amount to about

1.5 BeV per particle on the average, this is another reason why low-energy primary cosmic rays cannot reach the surface of the earth.

More recently the possibility was recognized that many particles unable to reach the earth might be trapped at some elevation (as shown in the following sketch), where they may spiral



There are two of these Van Allen Belts, one on the east (as in the diagram) and one on the west of the earth.

back and forth between the earth's poles and form a belt of high energy rays. The existence of such a belt of radiation, called a "Van Allen Belt," has been confirmed by high altitude measurements with rockets and satellites.

The magnitude of the latitude effect indicates that incoming rays are chiefly positively charged particles. Measurements were made of the relative numbers of cosmic rays arriving from the east and from the west. And they indicated that slightly more rays come from the west than from the east. This is known as the "east-west effect" and it indicates that incoming primary rays are mostly positively charged particles. High altitude rocket measurements now give more direct information and confirm that the incoming primary rays are mostly protons with alpha particles next and traces of heavier nuclei in about the same relative abundance as that of the elements in the known universe. Nitrogen, oxygen, magnesium, silicon iron and others have been detected. These may be distinguished by the fact that the most massive particles produce more dense tracks in a nuclear emulsion.

Emulsion Plate

NO.

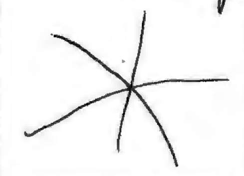
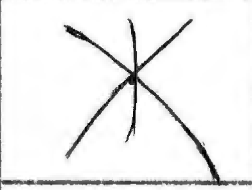
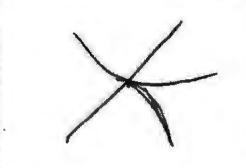
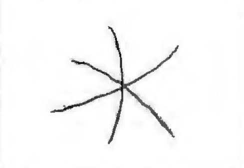
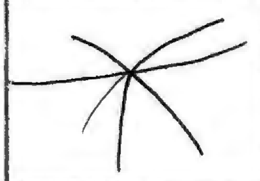
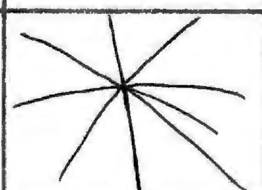
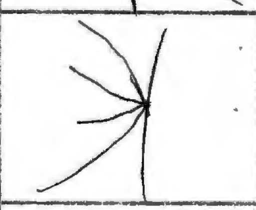
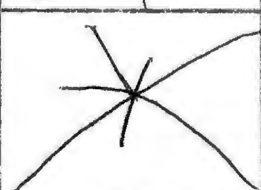
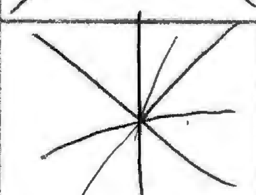
1169 59

magnification: eyepiece 10x

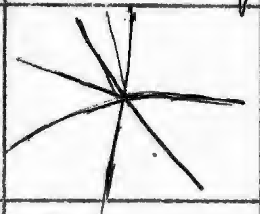
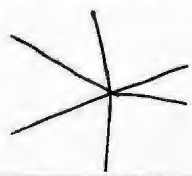
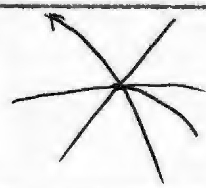
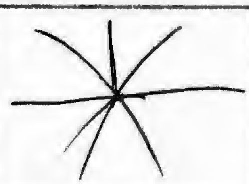
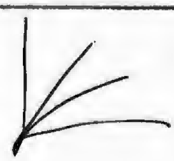
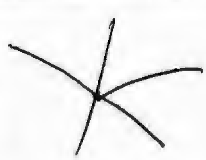
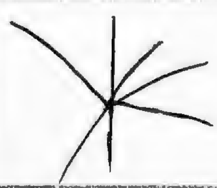
lens 40 B.M.

with reasonable light intensity control (avoid chemical reactions on the emulsion plate).

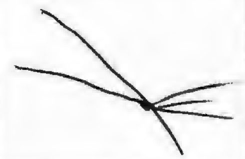
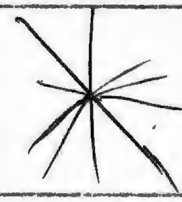
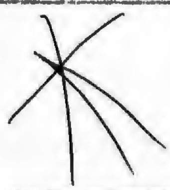
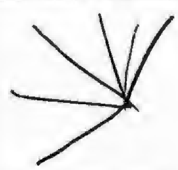
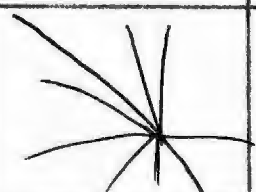
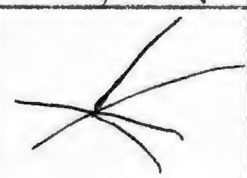
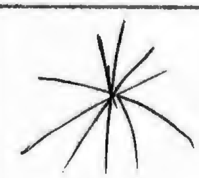
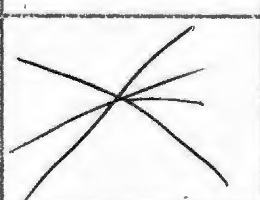
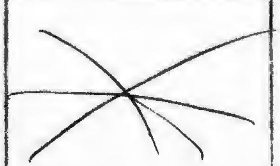
a = from air   g = from glass

Event No.	Description by drawing	ray direction	X-axis	Y-axis	Remarks
1		g	87.0	5.1	medium tracks
2		g	91.7	5.4	medium tracks well distributed on four quadrants
3		g	77.6	5.5	medium tracks.
4		g	79.9	6.3	light tracks
5		g	89.5	6.5	medium tracks with barely light a collision
6		g	91.8	6.5	heavy and well distributed tracks
7		g	97.7	6.7	medium tracks, lean on the left.
8		a	99.0	6.9	medium tracks.
9		a	100.5	6.9	long but light tracks.

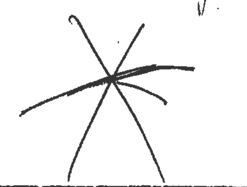
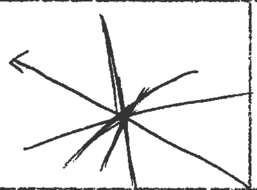
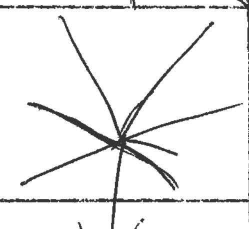
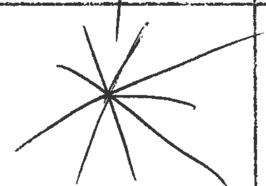
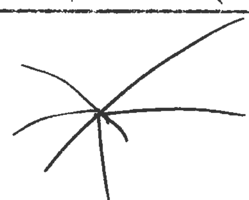
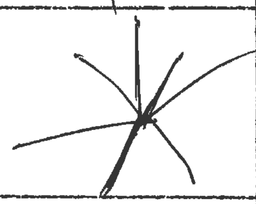
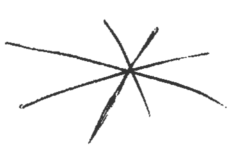
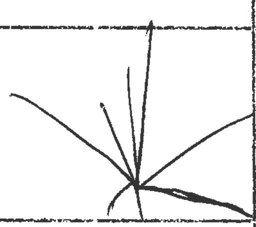
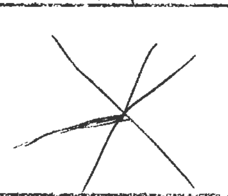
a = from air g = from glass

Event No.	Description by drawing	ray direction	X-axis	Y-axis	Remarks
10		?	73.5	7.0	rather heavy
11		?	77.0	7.2	light and short tracks
12		g	81.0	7.25	long but light tracks
13		?	85.3	7.2	light tracks
14		a	87.3	7.2	fairly long and medium tracks (intensity)
15		g	79.6	7.3	medium tracks tend to the top more
16		g	85.9	7.3	long tracks and tend to go to top right
17		a	100.0	7.3	short tracks
18		?	101.5	7.3	medium tracks

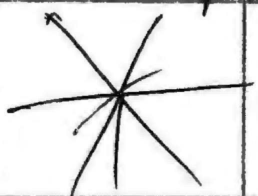
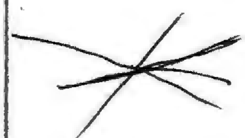
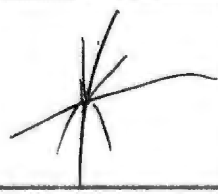
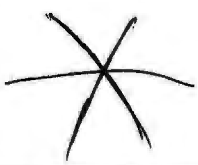
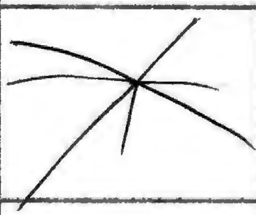
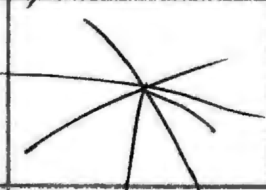
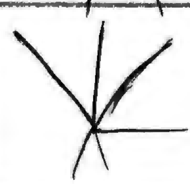
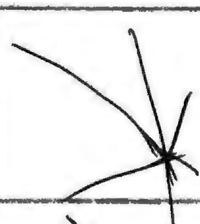
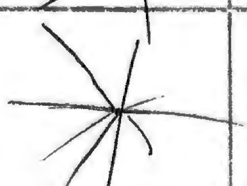
a = from air g = from glass

Event No.	Description by drawing	ray-direction	X-axis	Y-axis	Remarks
19		a	74.0	7.4	long tracks on the left.
20		g	74.3	7.5	tracks are well distributed, long.
21		g	79.8	7.5	light tracks, longer on the bottom
22		?	75.8	7.6	medium tracks, tend to the right more
23		a	99.3	7.6	long tracks tend to go to the top left.
24		g	102.1	7.6	medium tracks.
25		?	72.8	7.7	medium and dense (in distribution) tracks.
26		a	72.9	7.7	fairly long tracks
27		a	73.3	7.7	long but light tracks

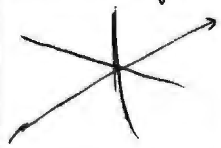
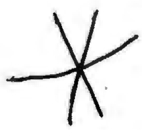
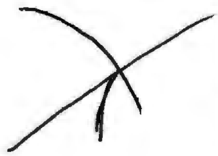
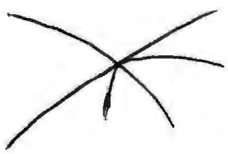
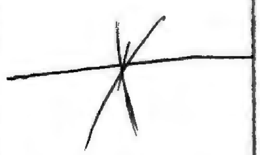
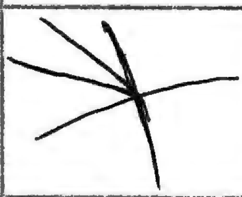
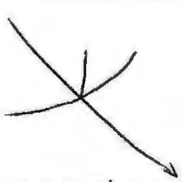
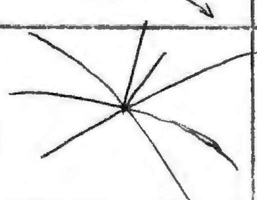
a = from air   g = from glass

Event No.	Description: by drawing	Description: ray-direction	X-axis	Y-axis	Remarks
28		?	81.1	7.7	medium tracks
29		g	74.3	7.8	heavy and long tracks
30		g	86.0	7.8	medium intensity but long tracks.
31		g	86.7	7.8	medium intensity but long tracks.
32		a	99.0	7.8	medium tracks tend to go to the right more
33		a	99.1	7.8	heavy and long tracks
34		?	80.2	7.9	light but long tracks
35		a	93.6	7.9	medium intensity but long tracks
36		a	94.9	7.9	light and medium tracks

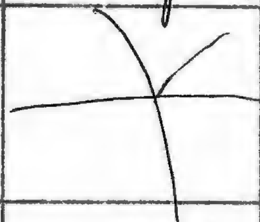
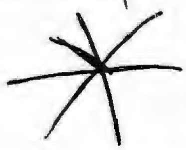
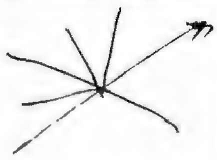
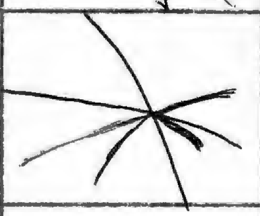
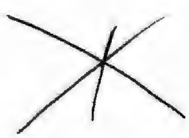
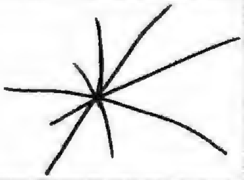
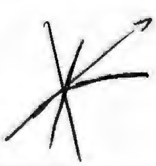
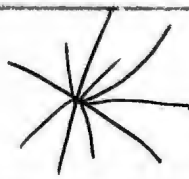
a = from air g = from glass

Event NO.	Description by drawing	ray-direction	X-axis	Y-axis	Remarks
37		a	69.8	8.0	heavy, well-scattered, long tracks
38		a	72.8	8.1	medium, well-distributed tracks
39		a	72.85	8.1	Ibid (neighbour to the previous one)
40		a	73.0	8.1	heavy but short tracks
41		g	84.6	8.1	well-scattered, long tracks
42		a	87.8	8.1	medium intensity but long tracks
43		g	93.6	8.1	heavy tracks, longer tracks on the top
44		g	86.8	8.1	medium intensity longer on the left side
45		g	85.3	8.2	long and well-scattered tracks.

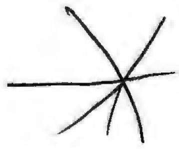
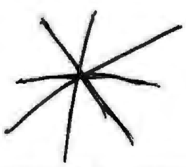
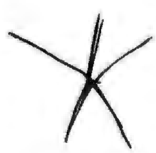
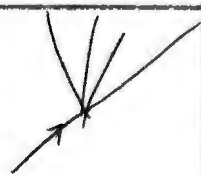
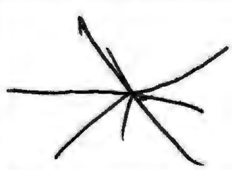
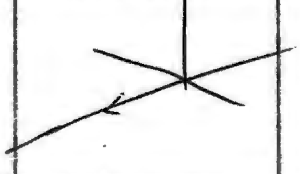
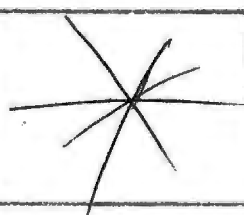
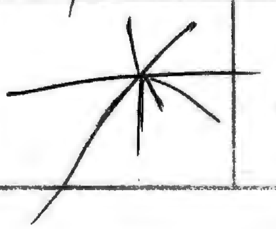
a = from air   g = from glass

Event No.	Description: by drawing	Description: ray-direction	X-axis	y-axis	Remarks
46		a	102.0	8.2	medium tracks
47		a	84.9	8.3	heavy but short tracks
48		g	86.9	8.3	long and medium (intensity) tracks
49		g	87.0	8.3	long and light tracks
50		g	99.5	8.3	barely collided or exploded particle.
51		g	101.1	8.3	Ibid
52		a	101.5	8.3	heavy tracks more on the top left.
53		g	102.0	8.3	light or barely collided.
54		?	70.1	8.4	long, but light tracks.

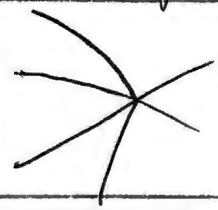
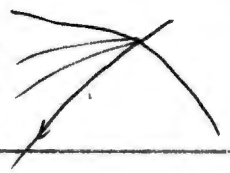
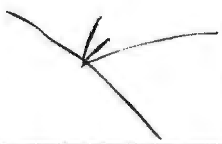
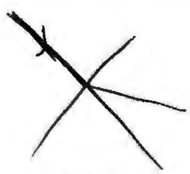
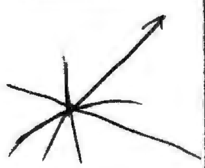
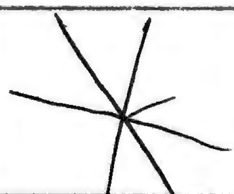
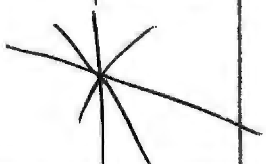
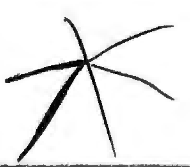
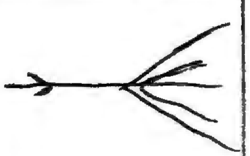
a = from air   g = from glass

Event No.	Description: by drawing	Description: ray-direction	X-axis	Y-axis	Remarks
55		?	71.5	8.4	long but light
56		g	73.1	8.4	heavy but short tracks.
57		a	87.5	8.4	light (intensity), medium tracks
58		a	87.5	8.4	neighbour to the previous one.
59		g.	87.9	8.4	long but partially heavy tracks.
60		g	99.5	8.4	short and light tracks
61		a	89.5	8.5	heavy and medium (size) tracks.
62		g	101.3	8.5	medium tracks
63		g	88.6	8.6	heavy and well-scattered tracks

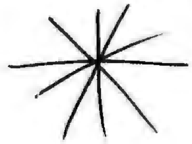
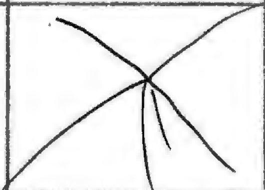
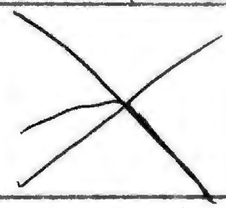
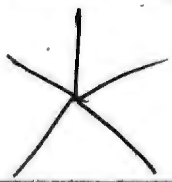
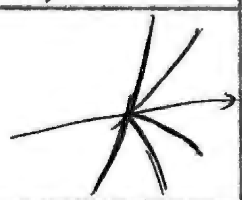
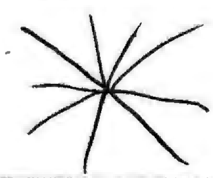
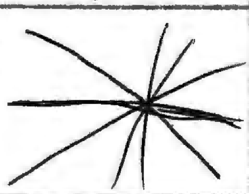
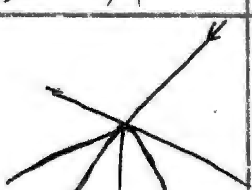
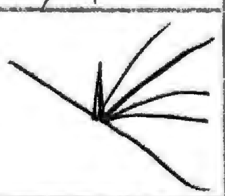
a = from air   g = from glass

Event No.	Description by drawing	ray-direction	X-axis	Y-axis	Remarks
64		g	101.3	8.6	tracks tend to be on the top right more.
65		g	90.3	8.7	medium, well-scattered tracks.
66		a	93.7	8.7	heavy and medium tracks
67		a	99.6	8.7	light and short tracks.
68		g	101.4	8.7	light, tracks on top more
69		a	85.6	8.8	heavy, well-scattered.
70		g	89.4	8.8	the arrow shows the direction of a particular long track
71		a	95.9	8.8	medium, well-distributed tracks.
72		a	86.2	8.9	heavy, partially long tracks

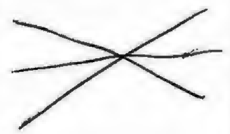
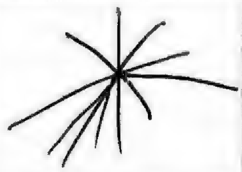
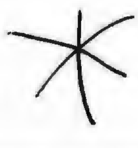
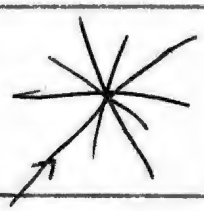
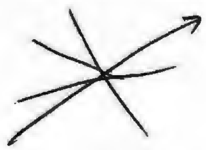
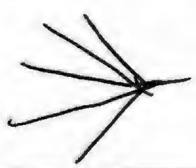
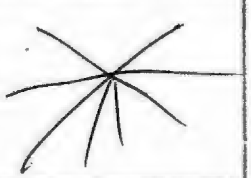
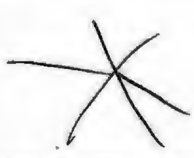
a = from air   g = from glass

Event No.	Description: by drawing	Description: ray-direction	X-axis	Y-axis	Remarks
73		g	91.9	9.0	partially heavy tracks
74		a	90.5	9.0	tend to left side more.
75		a	72.0	9.1	light on the top side
76		g	72.6	9.1	one heavy track (or ray) from glass and scattered the others
77		a	76.8	9.1	even-scattered with partially long tracks
78		g	84.9	9.1	heavy and even collisions.
79		g	73.9	9.2	heavy and medium (size) tracks.
80		a	69.2	9.4	heavy on the left and scatter out to the right.
81		a	70.5	9.6	a rather heavy

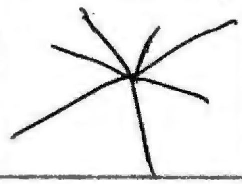
a = from air g = from glass

Event NO.	Description by drawing	ray-direction	x-axis	y-axis	Remarks
82		g	72.3	9.6	heavy, well-scattered tracks
83		g	77.3	9.6	long tracks
84		g	78.4	9.6	heavy track from bottom right and scattered the others.
85		a	80.4	9.5	well-distributed, medium tracks
86		a	87.4	9.6	heavy tracks, on the right-side.
87		g	87.9	9.6	heavy, well-collided tracks.
88		g	92.1	9.6	heavy, longer tracks on the left.
89		g	94.5	9.6	heavy tracks scattered more on the bottom
90		g	102.2	9.6	tracks tend to go to the top right more

a = from air g = from glass

Event No.	Description by drawing	Description ray-direction	x-axis	y-axis	Remarks
91		a	67.7	9.7	medium, even on both sides.
92		g	72.7	9.7	medium but heavy tracks
93		g	78.8	9.7	heavy but short tracks.
94		a	88.3	9.7	heavy and reasonably ~~long~~ tracks.
95		g	101.8	9.7	medium tracks on the bottom
96		a	110.0	9.75	medium tracks
97		g	88.5	9.8	medium tracks on the left side
98		g	79.0	9.85	medium (intensity) but long tracks
99		a	69.2	9.9	medium tracks

a = from air   g = from glass

Event No.	Description by drawing	ray-direction	X-axis	Y-axis	Remarks
100		g	104.0	9.9	heavy, partially long tracks.
101					
102					
103					
104					
105					
106					
107					
108					

Read References

Cosmic Rays. — Bruno Rossi —
Atomic and Nuclear Physics — R.D. Rusk —
Cosmic Rays — Leprince & Ringuest —
The Universe — Issac Asimov —
Nuclear Research Emulsion — Barkas —
Solar System Astrophysics — Brandt & Hodge —
Sunspots in Action — H.T. Stetson —
A Star Called the Sun —
Nuclear Physics and the Fundamental Particles — Heckman & Starring —