Cosmic Ray Tracks Observed by New type Cloud Chambers

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Abstract—**We have fabricated two different types of cloud chambers: a diffusion cloud chamber and a Wilson cloud chamber. These chambers were filled with air and the tracks formed in them by cosmic rays were investigated. Surprisingly, cosmic ray tracks were observed in air containing few aerosol particles. This finding is highly significant and may be useful in future studies of the relationship between solar activity and global cloudiness.**

1. The Correlation of Friis-Christensen and Svensmark

WHETHER cosmic rays affect the global climate is an important unresolved question in geophysics. This question was first posed in a paper by Friis-Christensen and Svensmark published in 1997 [1]. In subsequent papers, Svensmark et al. found a correlation between global cloudiness and the intensity of cosmic rays [2, 3, 4]. According to their analysis, global cloudiness increases when the intensity of galactic cosmic rays, i.e., cosmic rays originating from outside the solar system increases. A clear correlation has also been found between the cloudiness at low altitudes (under 3,200 m) and solar activity. However, no correlation has been discovered between solar activity and the cloudiness at middle and high altitudes. Due to the correlation at low altitudes being so strong, a vigorous debate has ensued in various scientific fields.

Cosmic ray physicists have no difficulty understanding the correlation between the intensity of cosmic rays and cloudiness, since they use cloud chambers to detect cosmic rays, which produce tracks in the chambers by ionization. However, the intensity of cosmic rays appears to be too low to account for number of water droplets in global clouds. Ion pairs induced by cosmic rays probably play only a minor role in accelerating the formation of water droplets. Even if cosmic rays were able to accelerate the formation of a small number of water droplets by ionization, the clouds produced would mask the light of the Sun, thereby reducing the global temperature. Thus, it might be possible to find a reasonable explanation for the correlation found by Friis-Christensen and Svensmark. In the next section, we discuss a scenario proposed by them.

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2. The Mauder Minimum and Cloud Formation

During 1645 and 1725, an abnormally low number of sunspots were observed on the solar surface [5]. This phenomenon is known as the Maunder minimum. It coincided with an approximately 2ºC drop in the average global temperature. Due to the weakness of the solar magnetic field during this period, the intensity of galactic cosmic rays was stronger than at other periods [6-8]. Thus, the correlation found by Friis-Christensen and Svensmark would be possible to explain the drop in global temperatures that occurred during the Maunder minimum [9]. The aim of this present study is to find an explanation of the correlation observed by Friis-Christensen and Svensmark.

As a first step towards this goal, we approach the correlation from another point of view. A widely accepted theory by meteorologists is that when warm air ascends to high altitudes, it is cooled and the moisture it contains condenses to form clouds. Both water vapor and aerosol particles (APs) are necessary to form a cloud. This can be easily demonstrated by blowing smoke from a match into a vessel filled with water vapor, which results in the immediate formation of a cloud [10]. In summary, *both* the water vapor and the APs are necessary for cloud formation [11]. This is the standard theory for cloud formation.

However, the cloud formation process is not so simple: Aitken particles also play an important role. Aitken particles are typically about 20 nm - 80 nm in diameter, which corresponds to the length of a few tens of water molecules. They are so small that they cannot be detected by optical counters. The mass of Aitken particles can be determined by measuring the time that it takes for ionized Aitken particles to drift when they are placed in an electric field. Aitken particles undergo successive collisions with water droplets in air and thereby increase in size until they reach diameters of about 1 μm, which is the size of a large AP. Observations at the Mt. Norikura Cosmic Ray Observatory (altitude: 2,770 m) indicate that Aitken particles in the atmosphere grow from 10 nm to 30 nm in approximately 8 hours [12]. For simplicity, however, we do not consider the role of Aitken particles in this paper. Rather, we regard APs as being the principal source of cloud condensation nuclei (CCN).

In addition, the role of the ions created by cosmic rays is not well understood. There may be other routes through which ions have function as CCN and form water droplets. Do ions accelerate the formation process of CCN? Or do ions increase in size by attracting water particles by themselves, independently of Aitken particles and/or APs? This is a very critical point for understanding the Maunder minimum phenomena. In order to discover the answer to this question, we conducted an experiment using small cloud chambers. In this paper, after describing our experimental method, we present the results and introduce our future plans.

3. Experimental Method

Do ions produced by cosmic rays agglomerate by themselves? Or do they attach to the surface of Aitken particles and/or APs? In order to clarify this point, we fabricated specially designed cloud chambers and used them to conduct experiments.

We prepared two types of cloud chambers: a diffusion cloud chamber and a Wilson cloud chamber. While these cloud chambers are similar to conventional cloud chambers, they differed in that the gas inlet and outlet was located on the outside of the chambers. Figure 1 shows schematic views and photographs of these diffusion and Wilson cloud chambers.

We used purified air and nitrogen manufactured by the Sumitomo Seika Chemicals Co. which had very low levels of APs in them (less than one AP per liter according to the manufacturer). In general, there are high quantities of APs in the air. Table I shows the number of APs per liter measured in the air in the laboratory and outside the building. These APs were measured by using the optical particle counter. In Table I, the number of aerosols per liter is presented as a function of AP size.

We investigated the formation of tracks by cosmic rays in the purified gases. Ethanol was placed in the bottom of the glass flask and also at the top of the flask. First, we passed gas through both chambers until the total amount of gas passed through each chamber exceeded five times the volume of the chamber. According to our calculations, this process increased the purity of the gases by a factor of 160 (i.e., 6×10^{-3}).

We cooled the diffusion cloud chamber by putting solid CO_2 at the base of the glass flask and waiting approximately 30 min until the vessel had cooled down and a saturated layer had formed, which was capable of producing cosmic ray tracks. For the Wilson cloud chamber we just lowered the piston and expanded the volume; this formed a supercooled region.
We have recognized the cosmic ray tracks by the naked eye, being illuminated the cloud chamber by the photo diode.

4. Results and Discussion

Surprisingly, cosmic ray tracks were observed in the semi-purified air in the same way that they were observed in the contaminated gas that contained a high concentration of APs. We are currently unable to explain this observation. It appears that ion pairs generated large droplets without the assistance of APs. Is there a previously unconsidered third route to make CCN? Do ions form water droplets by themselves? Our experimental results suggest that this is possible.

However, there are several questions concerning the quality of our experiment. Even although we used "pure" air, the purification process was not perfect. Some APs might remain not only on the chamber wall but also in the gas itself. The baking of the chamber wall is not easy. Even if the air contained a small amount of APs, ion pairs may form to the large water droplets. Furthermore, we did not measure the amount of Aitken particles in the semi-pure air. The air might have been relatively free of Aitken particles, but it is unlikely that there were no Aitken particles present. It is unclear role ethanol vapor plays. Does it behave like Aitken particles in the flask for ions?

We observed experimentally that ions generate cosmic ray tracks. This is similar to the results of an experiment conducted by Sir Wilson. He investigated cosmic rays using a Wilson cloud chamber. Initially, he observed a lot of fog in his cloud chamber. However, after repeatedly expanding the cloud chamber, he observed cosmic ray tracks. In the initial stages, the water droplets were formed by attaching to APs inside the chamber. However, it is unclear whether the cosmic ray tracks observed at later stages were formed with the assistance of Aitken particles or APs that remained in the chamber. If this is true, Sir Wilson was lucky to observe cosmic ray tracks. To confirm this point, we need to conduct another experiment using vessels that have been purified more. We intend to investigate the cloud formation process by using a vacuum chamber and report the results at the next ICRC at Lodz.

Size of Aerosols	>0.3 μm	>0.5 μm	>0.7 μm	>1 μm	>2 μm	>5 μm
Outside	309,447	35,578	7,907	2,822	884	87
Inside	175,698	14,107	3,634	1,558	675	71

Table I: The number of APs per liter measured in the air inside the laboratory and outside the building. The data are given as a function of the size of the APs.

Note added: Recently we have conducted an experiment using the diffusion cloud chamber. The chamber was filled with the pure air after the evacuation inside the chamber by the vacuum pump. Neither any track nor fog was seen. However when we installed a ring that was involved with a plenty of the Ethanol at the top of the flask, clear tracks of cosmic rays and also fogs were seen even in the "pure" air. (November 3rd, 2008)

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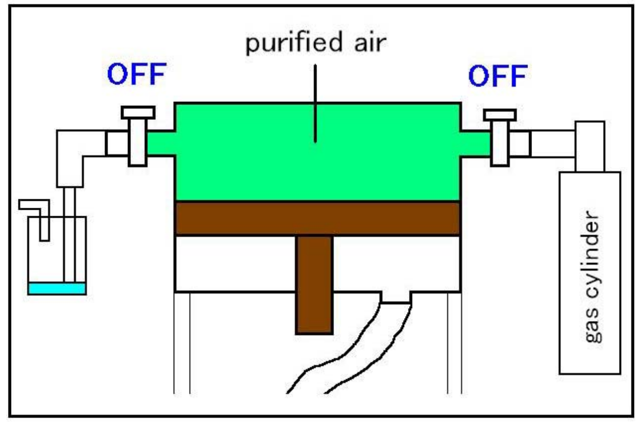

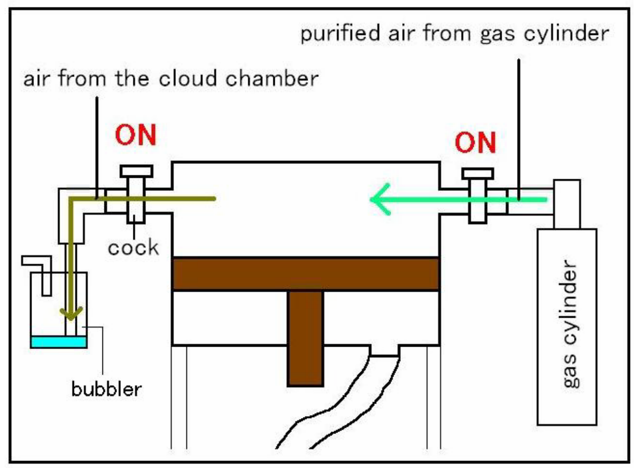

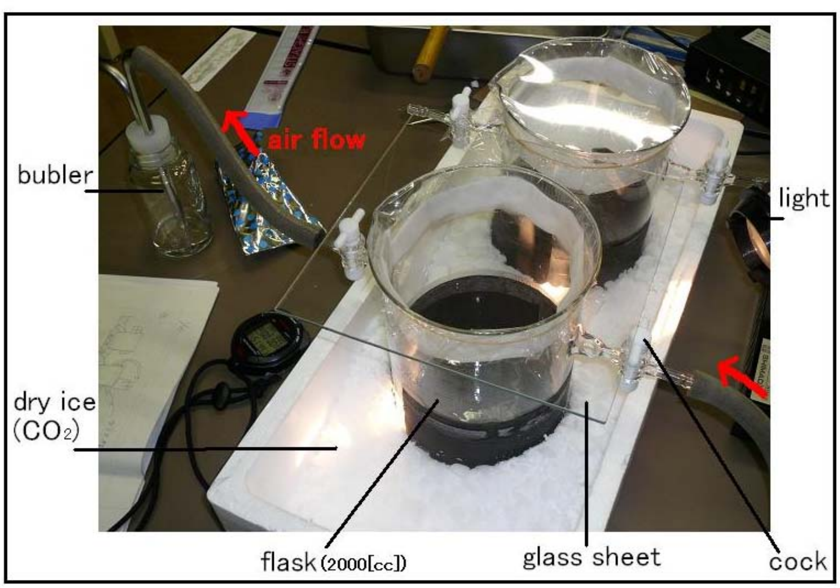

Figure 1. The bottom left panel shows the diffusion cloud chamber. The top right panel shows the Wilson cloud chamber filled with pure air and the center panel shows how purified air was introduced into the Wilson cloud chamber. The bottom right panel shows the Wilson cloud chamber that we made.