Atmospheric Transparency Measurments of Desert Air in Utah for the Telescope Array Project

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Abstract

A Japan-US collaboration group began new experiments to measure the atmospheric transparency of desert air in Utah. They are the R & D works for the Telescope Array Project. Japanese group installed a laser system and $1.5m$ diameter mirrors on a $HiRes-I$ hill to observe the back scattered lights of laser pulse. A scheme of the system and some data will be presented.

1 Introduction:

Two groups of $AGASA$ and $HiRes$ have recently reported several events of ultra high energy cosmic rays beyond $10^{20}eV$. A Japan-US collaboration group is working on the preparations for Telescope Array Project which is proposing to build ten mirror stations separated in about $30km$ with each other. In this project it is essentially important to determine the cosmic ray energy which is obtained by the observed intensity of scintillation lights emitted from the cosmic ray air shower and by the distances from receiver mirror station to the shower. The observed light intensity could strongly depend on the atmospheric transparency. In addition the light is $300 \sim 400nm$ UV whose intensity could rapidly be attenuated in atmosphere.

2 Experiment:

A laser shot system and two receiver mirrors have been installed in a hut on the top of the $HiRes-I$ hill ($1600m$ a.s.l.) in Utah in Nov 1998 as shown in Fig.1. It is called a Lidar (Light Detection and Ranging) system which measures the back scattered light power of laser pulse shot into atmosphere. The laser emits $355nm$ UV pulses in $10Hz$ max with energy of $66mJ$ max. A laser pulse is splitted by the optical mirrors to two directions of $3°$ and $15°$ in elevation angle emitted into the atmosphere. Two receiver mirrors are viewing toward the directions of two laser beams in parallel. The back scattered light are received by $1.5m$ diameter mirrors and are focused on $2inch$ PMTs viewing in the angle of $\pm 0.9°$. The current signals from PMTs are measured by digital oscilloscope and recorded into CPU. A whole of the system is operated by CPU control.

In a tentative model of atmosphere, the back scattered light power $P(X)$, X is the atmospheric depth($g \cdot cm^{-2}$), is assumed to be expressed as follows;

$$P(X) = C(P_0) \times density(h) \times T(X) \times R^{-2}$$

$C(P_0)$ is a system constant. The $density(h)$ is the columen density of atmosphere at the scattered area as a function of scale height h; $h = R \times sin(elevation\ angle)$, in which it could be assumed to be expressed in $exp(-h/h_0)$, h_0 is a scale height constant. R is the distance between the emitted/received point and the scattered area in atmosphere along laser beam. $T(X)$ is the transparency function which would be given by

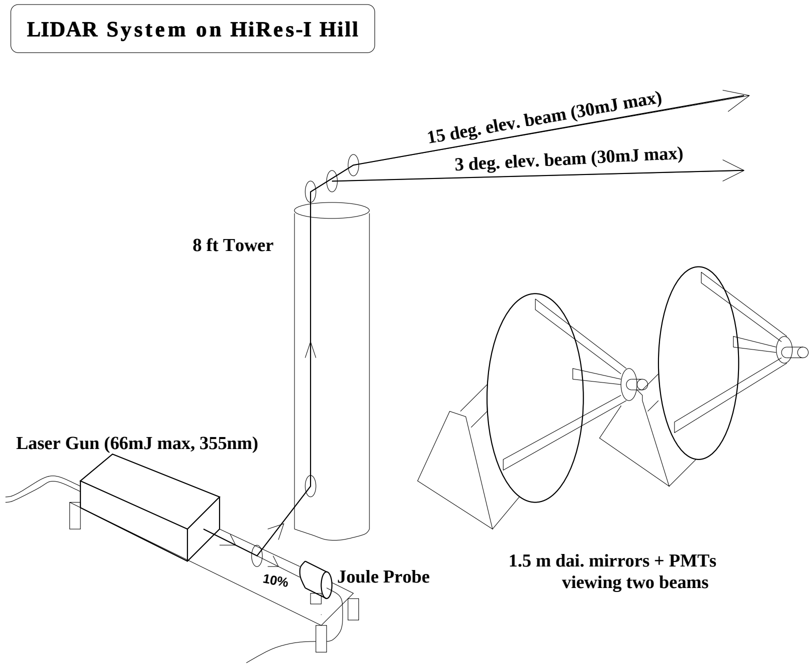

Figure 1: The Lidar system installed on HiRes-I hill

the observed data.

Fig.2 shows an example of observed result of back scattered light power $P(X)$ as a function of the atmospheric depth $Xg \cdot cm^{-2}$ along laser beam of 3° elevation angle. The power intensity in the figure is ploted in $ln(P(X) \times R^2/density)$. The example in Fig.2 gives us a transparency formula as a result;

$$T(X) = exp(-X/\lambda(X))$$

$$\lambda(X) = 1460g \cdot cm^{-2}, \quad \text{for} \quad 1000 < X < 3000$$

The lambda (λ) is the mean attenuation depth which is, in general, a function of depth X at the scattered area. The constant value of lambda for the example above indicates that the atomspheric materials are distributed in uniform in the depth range of $1000 < X < 3000$. The value of $1460g \cdot cm^{-2}$ is corresponding to $14km$ in horizontal distance at this level. The data above have been obtained on 26th November 1998. It was a good transparency at that time. The same values of lambda have also been obtained in the following two nights.

Fig.3 shows another data observed on 22nd April 1999. The lambda value is not a constant but changing with the depth of scattered area. It indicates that the lights are scattered by dense materials, maybe aerosol, in near range of distance, and the material density is distributed in changing gradually to be thin with the distance.

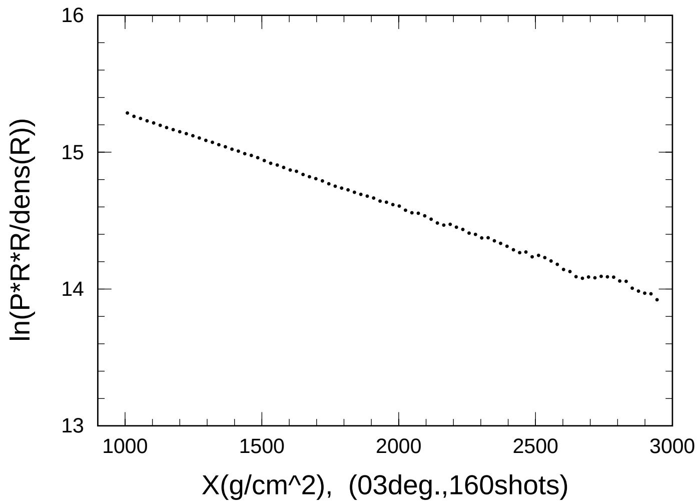

Figure 2: An example result of back scattered light observed on 26 Nov 1998.

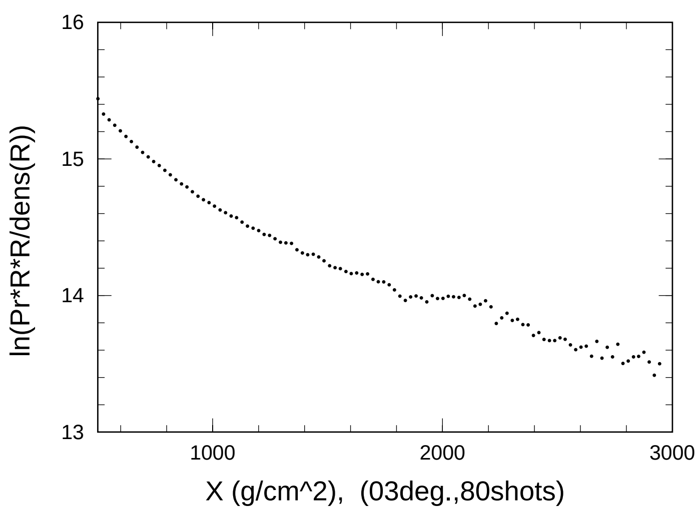

Figure 3: Another result of back scattered light observed on 22 Apr 1999.

Fig.4 shows the time variation of mean attenuation depth during 24 minutes observed on 26th November 1998. The error of lambda value is $\pm 50 g \cdot cm^{-2}$. It looks quite stable at that time.

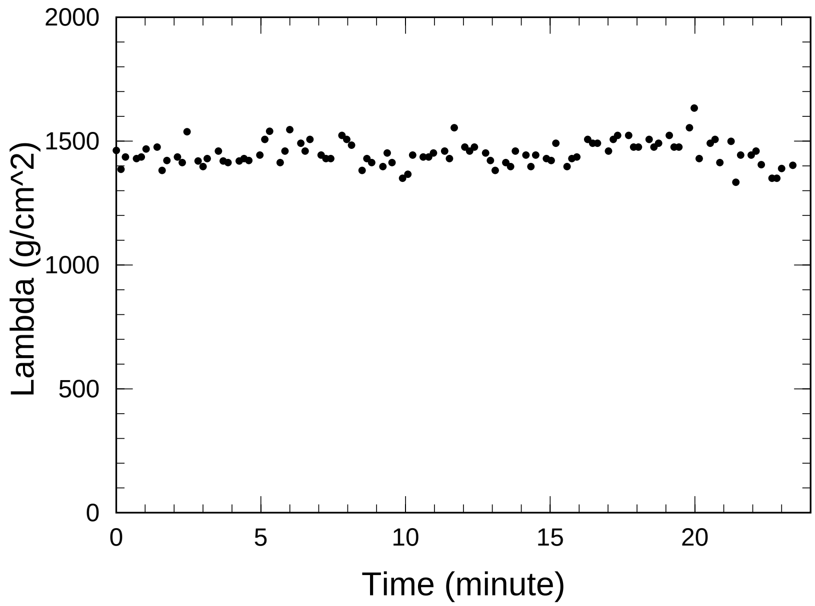

Figure 4: The time variation of mean attenuation depth during 24 minutes.

3. Discussion:

In general, the power of lateral scattered light depends on the phase angle between the laser shot direction and the viewing direction of receiver mirror, and also depends on the polarizing phase angle of laser pulse as shown in another paper (OG.4.5.17). The Lidar data are free from the dependences on them because of a fixed phase angle of 180° for back scatter and of keeping a perpendicular to the polarizing light phase. Therefore the Lidar is a easy method to observe the atmosphere as well as the whole system is installed and controlled in a room.

On the other hand, in analyzing Lidar data we should notice an assumption in which the mean attenuation depth of going laser light power is equal to that of coming back scatterd light power. We need to compare the Lidar data to those of other method observation.