The change in Cosmic rays intensity variation with the Solar wind velocity variation
(Using GRAPES-3 muon narrow angle telescopes and Kiel neutron monitor)

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Abstract: GRAPES-3 experiment is situated at Ooty in South India 76.7 East 11.4 North. Effective observation area of our muon telescopes is 560 m^2. They are the largest detector in the world of its kind. There were several reports that increase of the solar wind velocity suppresses the intensity of cosmic rays. But there are few which studied qualitatively. We have analyzed the variation of daily mean of counting rate of low energy muons >~1GeV along with Solar wind velocity. Our muon telescope data are used together with Kiels'neutron monitor for 2000 to 2005. These 6 years correspond to solar maximum to minimum. Period for Forbush decrease has been removed from analysis to avoid unusual response of muons rate during those periods. In case of muons their intensity decreases with Solar wind velocity -0.0013% per km/s with relative coefficient of 0.97. For Neutron Monitor it is -0.0032% per km/s with relative coefficient 0.96. These results suggest there is clear correlation between Solar wind and the intensity of cosmic rays. Significant change in their slope were seen between first 3 years data and latter 3yeras one. We describe about them in detail in the report.

Introduction

The diffusion coefficient for the propagation of cosmic rays is required to describe the density of cosmic rays which is penetrating into the solar system from inter stellar space. According to the Diffusion and Convection theory, the intensity of cosmic rays varies with the variation of solar wind velocity. If we can clarify the relation between those two quantitatively, it would be useful to obtain the diffusion coefficient for the propagation by observation.

There were several report so far that cosmic rays intensity decrease with the increase of solar wind velocity (we call this phenomena as cosmic rays - solar wind effect) since the beginning of the direct measurement with satellite (October 1963). Those report is mostly concerned with the cosmic rays intensity with high speed solar wind. There are a few works that is done for the cosmic rays intensity variation with the solar wind variation qualitatively. The main reason is the following.

There are two kind of intensity variation in the cosmic rays, one is long term variation such as 11 years of solar cycle, other is short term variation like Forbush decrease. Other than these variation there are some variation due to the Earth's revolution of its own and around the Sun.

These different cause over up each other in the ground level observation. In case of solar wind several variations are seen, such as high speed

solar wind with solar flare, 27 days cycle of solar revolution and some several years variation. It is quite tough to isolate the genuine variation from those various causes. The simple comparison in the cosmic rays and solar wind seed variation would not be able to create successful explanation.
Some report suggest that direction of galactic cosmic rays flow into the solar system change their direction with its of solar magnetic dipole field. If we can find the North-South direction effect on cosmic rays solar effect, it must be very useful to explain the cause of cosmic rays flow into the solar system.
We are measuring muon's directional intensity variation from 1999 on ward. Our apparatus are situated at south India (76' 40" East and 11'23" North, 2200 a.s.l.) and consist of 16 independent modules, each module has effective area of 35m2 and total size of 560 m2. This is the largest muon telescope in the world for muon measurement.
We have analyzed muon directional intensity variation data for 6 years, 2000 to 2005.
It covers the duration of the maximum to minimum of solar activity. The neutron monitor's data from Keil were also analyzed for same period.
In order to remove the various components which arise from many cause described above we applied digital filtering of 27days period on both cosmic rays and solar wind velocity. We could remove the long term contamination. The short term variation due to the Fprbush decrease have been estimated by removing the period which shows more than 2% decrease in the Kiel's neutron monitor.

The followings are the results from the analysis.

Analysis and Results

Analysis has been done by using 2000 to 2005 six years data of both Kiel's neutron monitor and GRAPES-3's muon directional observed data.
The detail of our apparatus can be seen in articles. Even though we can measure the rather detailed feature in muon's direction, we categorized those muon into 9 direction.
See in fig.1. Fig.2 and fig.3 shows the variation of intensity of muon and neutron and solar wind velocity.

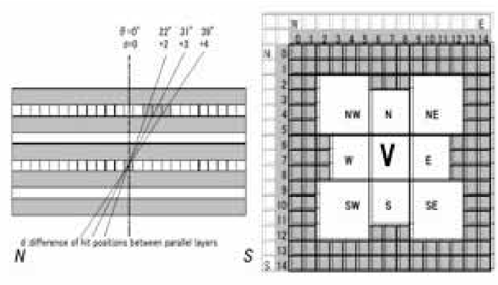

Fig1． GRAPES3 muon narrow angle telescopes observed direction

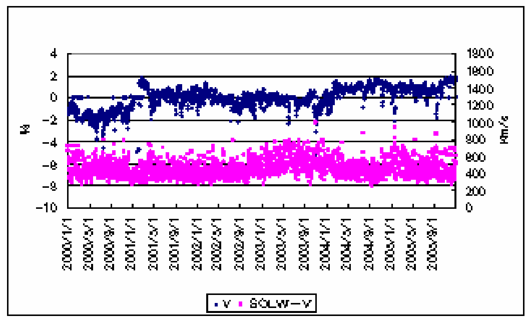

Fig2.GRAPES3 muon(V) and solar wind velocity

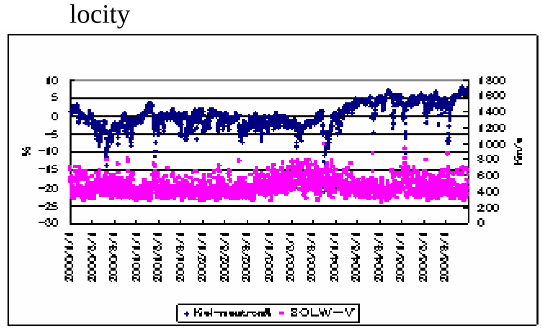

Fig3.Kiel neutron and solar wind velocity

One can see the long term intensity variation in addition to the daily variation in both cosmic rays intensity and solar wind velocity. The amount of variation is ~3% in case of muons intensity and ~8% in case of neutron for 6 year's duration. In case of solar wind velocity amplitude of ~100km/s with ~3 years cycle can be seen. This long term variation looks due to the part of 11 years solar activity. It is known that there were some several years variation due to the appearance of coronal hole. In any case it seems to be extremely difficult to extract the genuine cosmic rays intensity solar wind effect from the raw data, since there are quite a few contamination.

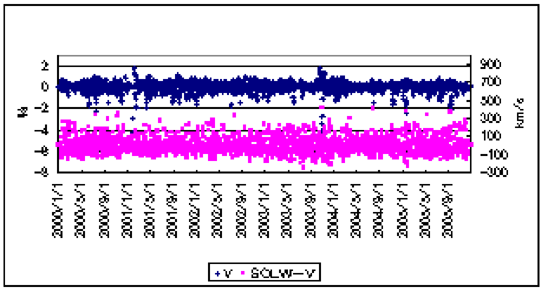

Fig4. GRAPES3 muon V and solar wind speed after high-pass filter is processed of the 27day period

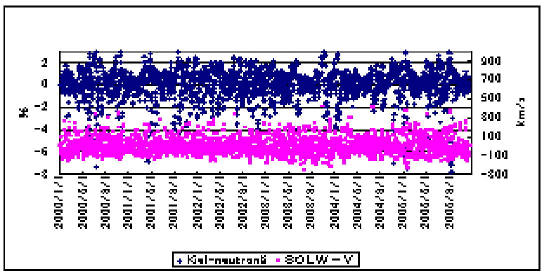

Fig5. Kiel neutron and solar wind speed after high-pass filter is processed of the 27day period

As you can see clearly in the fig.4 and fig.5 the long term variation are removed from both cosmic rays intensity and solar wind velocity. After processing with the filtering, the data are sorted by the solar wind velocity in sec. into next 7 groups, v<–80km, -40km<v<-80km, -40km<v<0km, 0km<v<40km, 40km<v<80km, 80km<v<120km, 120km<v. The average are calculated for each group for these 7 groups and regression analysis has been applied with solar wind velocity variation as independent variable and cosmic rays intensity variation as dependent variable. The results are shown in fig.6 ~fig.9.

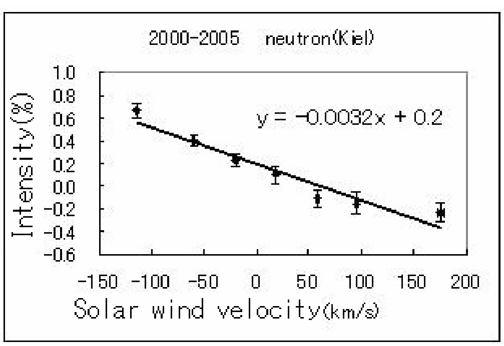

Fig6. Solar wind velocity variation(x) and neutron(Kiel) intensity variation(y)

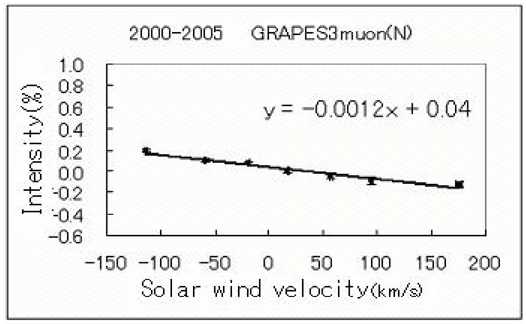

Fig7. Solar wind velocity variation(x) and muon(N) intensity variation(y)

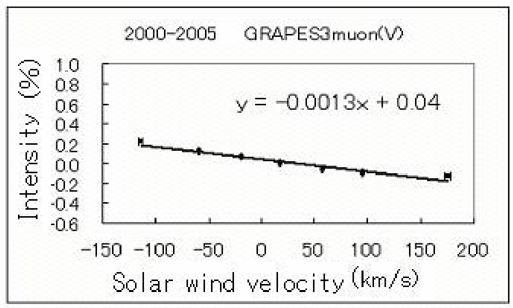

Fig8. Solar wind velocity variation(x) and muon(V) intensity variation(y)

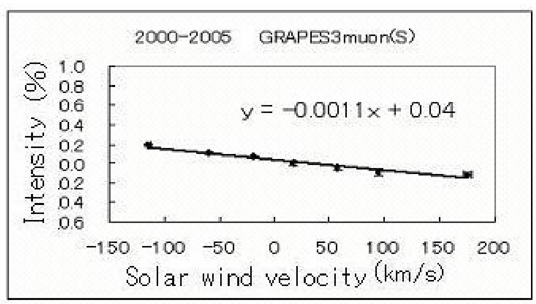

Fig9. Solar wind velocity variation(x) and muon(V) intensity variation(y)

One can see clear tendency that cosmic rays intensity variation decrease with the increase in solar wind velocity variation. The slope for neutron is larger than muon's slope. We split the 6 years data into two group of 3 years, 2000~2002, 2003~2005 and repeat the same analysis. Those results are shown in fig.10 ~ fig.13.

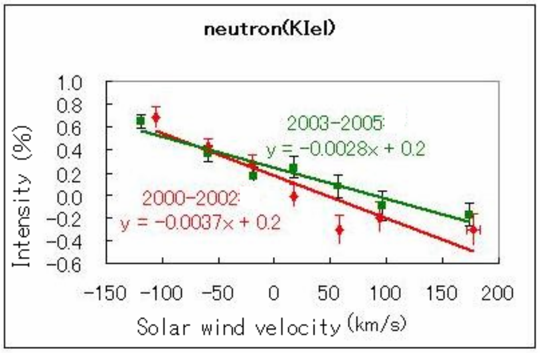

Fig10. Red: 2000~2002 Green: 2003~2005

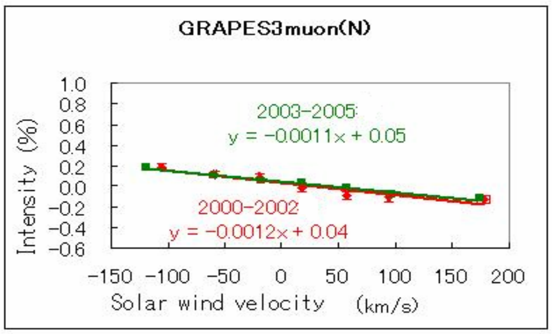

Fig11. Red: 2000~2002 Green: 2003~2005

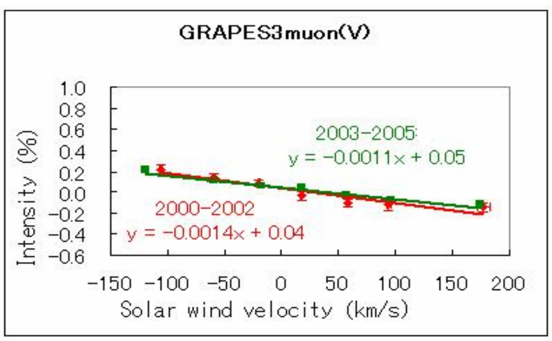

Fig12. Red: 2000~2002 Green: 2003~2005

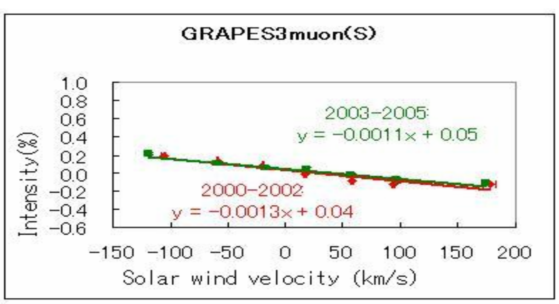

Fig13. Red: 2000~2002 Green: 2003~2005

The earlier 3 year's results seems to be slightly steeper than later 3 years. It may be suggesting that there may be some effect of solar activity.

Conclusion

So far it is pointed out often that there are some temporal effect of solar wind velocity variation on cosmic rays intensity variation due to the solar flare. Our present analysis suggest that the cosmic rays intensity variation decrease with the increase of solar wind velocity variation strongly. The effect of the solar activity also has been seen. We have introduced the cosmic rays muon data along with the usual neutron monitors data in this analysis. We could perform the detailed directional analysis using muon's data utilizing the very large area of detection. We could not find any significant effect on north-south effect.

Acknowledgments

On this analysis. The solar wind velocity used the data of ACE level 2. Neutron intensity used the data of the WDC observation station of Kiel. The sunspot number used the data of "Solar Influences Data analysis Center". We wish to express our gratitude to each organization that has disclosed data.

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