Academic Achievements of Minoru Oda in INS(1956-1965)

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I'm not sure when Oda made his mind to develop the new Air Shower Project in Japan. However, when he came home to Japan in 1954 (1955?), the founding of INS (Institute of Nuclear Study) in the University of Tokyo and its outline had been already fixed. After the decision to include the cosmic ray division in INS, the cosmic ray people contacted with Oda and they discussed about the planning of the new air shower project. In 1956, just before the opening of INS, the concerned committee discussed about the master plan and 5 physicists were appointed as the staff of the air shower division (Oda, Miura, Suga, Matano and Tanaka). Oda was naturally regarded as the leader of the group. In April of 1956, INS opened and they started to build the new air shower array with the members from the other universities (Fukui, Hasegawa, Kameda and Toyoda). I joined the group as a student after the autumn and was a staff after the next year. In the later time Shibata and Nagano joined the group in 1962 and in1963 respectively.

The characteristics of this array was to get the data of different components of each air shower and to study the mechanism of the development process in the atmosphere.

The constitution of the array was as follows.

Object	Kind of detector	Number
(1)Electron density	$1m^2$ plastic scintillation detector	14
(2)Electron density pattern	2cm dia neontube array — spark ch array	$7m^2$-$16m^2$
(3)Arrival direction	$1/4m^2$ plastic scintillation timing detector	5 (2.5ns)
(4)Electron energy flow	50cm dia 12r.l. Pb glass block detector	14
(5)Muon density	$2m^2$ plastic scintillation detector	4 undergr($\geq$1Gev)
		4 undergr($\geq$ 5Gev)
(6)Hadron energy	$1/4m^2$ x 4 5 layer Fe Pb calorimeter	1

The observation of the Air Shower(AS) started partly in 1958, and the full running of this AS array started in the spring of 1959 to observe 10^{14}eV - 10^{17}eV AS in the 50mx50m area of the backyard of INS. The data were analyzed mainly from the following three points of view.

The first point was to get the standard characteristic of each component of AS. This includes the lateral distributions of the components and their integrated value over the core distance — say the total number or the size — of the component for the different shower size of the electron.

The second point was the study of the shower core. To get the precise core location the lateral distribution of the electron was determined by means of both the neon tubes / the spark chamber array and the scintillation detectors. The result was agreed with the electromagnetic cascade theory of age 0.6 - 0.8 within 30m of the core distance. But it had the remarkable fluctuation from shower to shower within several meters from the core. Not only the fluctuation of the steep-ness of the distribution but sometimes the shower with two or three cores were observed within this distance. The production of the high energy particle with large transverse momentum was responsible for each of these cores. These transverse momenta are of 1 to several 10Gev/c which was very large compared with the particle produced in the lower energy. As for the energetics of the shower core, the concentrated shower energy in the core controls the shower development and the high energy hadrons obtained from the calorimeter could predict the shower developing process in the atmosphere. The developing process can also be obtained from the following $N_{\dot{e}}$-N_μ analysis. Odafs group got the consistency between them, and this was a progress on the general understanding of EAS.

The third point was the fluctuation problem in the AS development in the atmosphere. Among the component of AS the electron data has the best accuracy, and so the electron size is usually the standard of data classification. On the other hand the prediction of the theory is usually given for the fixed shower energy. We usually replace the AS energy with the AS size under the assumption that the AS size is proportional to the AS energy in the data analysis of AS. However, this assumption is sometimes too bad. Under the condition of fixed shower size, the lower energy shower which is much more abundant can penetrate the atmosphere down to the depth where the shower size develops to the adopted fixed size.

Miyake emphasized this problem. To avoid this problem, Hasegawa formulated a new method named "N_e-N_μ diagram" for the data analysis of AS. When the AS energy is fixed, the fluctuation of the shower development results the corresponding fluctuation of the AS electron size, but not so much of the AS muon size. This shows a general understand that the AS muon size N_μ is a better observable of the AS energy and the AS electron size N_e is a kind of observable of the development fluctuation of AS.

If the AS muon size is assumed to be proportional to the AS energy, and assuming the primary cosmic ray energy spectrum and the shower profile model, we have "N_e-N_μ diagram", the correlation map between N_e and N_μ with the shower flux. This is just the prediction of what is presented from the experiment. For example, the shower group of the fixed N_e includes many showers of different N_μ, say, the different shower energies. And their starting points distribute almost uniformly from the top of the atmosphere down to the level where the Nmax shower start. In this analysis, many of Odafs group looked like to expect the heavy nucleus showers to be separated from proton's around the upper edge of the distribution, but it didnft happen as it was. However it is worth to say that this analysis opened the way to understand the AS behavior quite better than ever. With this analysis Odafs group obtained the collision m.f.p. of the cosmic rays with the air nucleus. They also obtained the atmospheric depth of the maximum development and the attenuation length of AS particles which reflect the cosmic ray collision characters of the energy of 10^{14}eV - 10^{17}eV. This method of analysis now can be developed by the Monte Carlo simulation taking into account of the primary energy spectrum of cosmic rays.

Odafs group of INS derived the shower model which is consistent with their own data of air showers, but the parameters which define their shower model had too broad allowance. Besides this there were several experiments which are inconsistent with this. Main point of the dispute was the degree of the survival energy in the coreAand some of this problem was revised to the less active core hardly within this allowance. At the present time, the old problem of the development of AS becomes more clear by means of the direct observation of Flyfs Eye. However, the identification of the parent is still not clear. It is interesting that Odafs group dared to challenge to this difficult problem 40 years ago.

Besides INS Oda made an effort in the establishment of the Bolivian Air Shower Joint Experiment(BASJE) which was proposed in the MIT group in 1960. The idea was to find the very high energy cosmic gamma ray by selecting the very poor muon showers, and this was the first trial to attack the very high energy cosmic gamma ray. Oda set the foundation of the international collaboration adjusting the mutual management of INS and BASJE. BASJE had been one of the centers of the cosmic ray research in Japan for long time since. Nearly at the same time, Oda cut out the more than 2000 years old big cedar tree from the Yakushima island in the south west islands in Japan, and developed the new research project to follow the old cosmic ray intensity since more than 2000 years. The activity had continued until the open of the primary cosmic ray division in INS in 1972. After 1962 members of the group began to move outside, and in 1963 Oda visited MIT again. After 2 years in 1965 he left INS and devoted himself to the research of the x-ray astronomy in ISAS (The Institute of Space and Astronautical Science).

As described above, the AS project of INS finished many objects led by Oda since 1956. INS was built for use of all nuclear physicists and was managed along this policy. And so, the AS array was used not only by the INS group but also by the other groups. At that time the cosmic ray researches in Japan had been carried out in the universities, the Cosmic Ray Laboratory on the Norikura mountain and INS. In this circumstance INS always served as a kind of the communication center of the researches. In this sense Oda made a great contribution to the development of the cosmic ray research in Japan in these days. After Oda left, the new research projects started in INS. They are the observation of the super large air showers and the detection of the atmospheric fluorescence light from AS. The former was the detection of radio echo from the very high energy AS, and after several test experiments the effort continued to the collaboration with Akeno array. The latter aimed the direct measurement of the AS profile to avoid the above described fluctuation problem of the shower. The search started at Dodaira with 2m lens telescope and succeeded in the detection in 1969. Another topic of INS at that time was the finding of the nearly horizontal air showers observed in the spark chamber array, and its neutrino origin and the other possibilities were discussed. In 1976 the cosmic ray division of INS became independent as the Institute of the Cosmic Ray Research (ICRR). ICRR started the new AS project at Akeno. The Akeno array was designed to observe many components of AS, say like "N_e-N_μ" as the development of INS array in the higher energy. The fluorescence experiment was given up in Akeno project because of the night sky condition. In 1990 AGASA project has started the run as the extension of Akeno array and in 1995 the Telescope Array(TA) project has started. The project of the super large air shower developed to AGASA and the project of the detection of fluorescence is coming to TA in ICRR.

These two projects and OWL too also have their small sprout in the INS AS led by Oda.