CHAPTER II

EXPERIMENTAL DETAILS

II.1 Detection at Various Altitudes of Cosmic Ray Stars By Nuclear Emulsion.

Eighteen of Ilford G5 Nuclear Research Emulsion plates 300 microns thick were used in this experiment. The manufacturing date was twenty sixth November 1962, and the date of arrival at Bangkok being 19th December 1962. The plates were divided into five groups. Each group had two packets, containing two plates each. These four groups were exposed in four different places in Chiengmai at the same time on the first of January 1963 in vertical position. The rest used as background determination were developed at the Department of Physics Chulalongkorn University on the eighth of January 1963 after returning from Chiengmai.

One packet of plates in each group was processed on the twenty-fifth of February. The rests were processed on the tenth of April 1963.

The detail of places, exposure times etc. are given in Table I.

Places	Altitudes in meters.	Time of exposure in day.		Number of stars.	
				(A)	(B)
Wat Suan Dok	313.76	49	92	-	3,996
Doi Suthep	1,650.00	49	92	2,241	-
Doi Intanone	~2,000.00	49	92	1,767	3,539
Doi Intanone	2,595.00	49	92	1,701	3,525

(A) = after 49 days   (B) = after 92 days

II.2 The Development

The process of development of nuclear emulsion plates 300 microns thick is based on temperature development of Dilworth, Occhialini and Payne (18) as shown below:

Solution's Preparations:

a. Developer ("Brussels amidol" developer)

distilled water	1,000	c.c.
boric acid	35	gms.
sodium sulphite anhydrous	19	gms.
10% potassium bromide solution	8	c.c.
Amidol Johnson	4.5	gms.

Step 1

boric acid 35 gms. and sodium sulphite 9.5 gms. were dissolved in 500 c.c. distilled water at 60° C. This solution was cooled down to 20° C.

Step 2

Amidol 4.5 gms. and sodium sulphite 9.5 gms. was disolved in 500 c.c. distilled water at lower temperature than 20° C.

Step 3

the solution in step 1 was poured into the solution in step 2 gently.

Step 4

potassium bromide was added in the solution of step 3, then cooled down 5 °C.

b.	Stop bath: acetic acid	0.2 - 0.5 %	
c.	Fixing solution: Hypo	400	gms.
	sodium bisulphite	30	gms.
	water add to	1,000	c.c.
d.	Hypo indicator:		
	distilled water	180	c.c.
	potassium permanganate	0.3	gms.
	sodium hydroxide	0.6	gms.
	water added to	250	c.c.
e.	Glycerine solution:	0.5 - 1 %	

The development's process

1. The plates were soaked in distilled water at 5 °C. for 75 minutes.

2. Then they were soaked in "Brussels amidol" developer at 5 °C for 75 minutes. The chemical reaction did not occur because of low temperature, but the developer is allowed to penetrate through emulsions and the maximum penetrating power of the solution is approximately at 5 °C.

3. The developing action was set to work by warming the solution up to 23 - 25 °C for about 60 minutes.

4. The plates were cooled down to 5 °C for 30 minutes.

5. The plates were transfered to stop bath at 5°C. for 1 hour.

6. The stop bath was removed by washing in slow running water at 5° C. for 1 hour.

7. The unexposed silver bromide was removed by soaking the plates in fixing solution at 10° - 15° C. with agitation for 14 hours.

8. The plates were removed from the fixing bath and washed in slow running water 10° - 15° C. for 24 hours. The hypo was completely removed to prevent later fading of the developed image so that the hypo indicator was used to assure complete removal. Several drops of this solution, ordinarily violet in colour, when added to a sample of water containing hypo will turn to orange in less than a minute. On the contrary with large hypo concentrations, the result will be a yellow coloration.

9. A large shrinkage in thickness occured because of the silver bromide was removed during fixing. The emulsions were impragnated with sufficient glycerine after processing so that the final thickness may be brought to the original if desired. This step the time required was 45 minutes.

10. The plates were kept in a desiccator horizontally, using calcium chloride to dry for 3 days and were left to dry completely in air for 4 or 5 days.

A thin film of silver is usually formed on the surface of the emulsions during development because of high concentration of silver bromide in nuclear emulsions and its partial solubility in the developer. By using a wet chamois or the finger tips, silver deposits could be removed in final washing.

Alternatively, the microscope immersion oil and lens tissue may be used to wipe the silver off when the emulsion was completely dry. Cotton, moistened with alcohol or xylene was used in cleanning the microscope immersion oil.

II.3 Instrument and Experimental Procedure.

The Microscope.

A low power objective was used in the scanning. In the present work, a Cooke - Troughton Nuclear Emulsion Microscope type M 40364 was used. The microscope is equipped with eyepieces and objectives. In this experiment ~~using~~ a pair of x10 compensating eye-pieces and an objective of 10 magnifications were used.

Microscope Setting

The plate was placed upon the stage of microscope and with a low power objective (x10) in the operating position, the specimen was brought into focus by the motion which raises and lowers the stage.

The condenser iris was closed and using the condenser focussing adjustment, the iris was brought into focus. The iris aperture was set to the center of the field of view of the eyepiece by means of the two condenser centering screws.

The condenser iris was then opened and the lamp iris was closed and the field iris was brought into focus by means of the condenser focussing adjustment. The iris aperture was set to the center of the field of view by the two mirror adjusting screws in the base at the front of the instrument.

The electric light bulb was slided inwards or outwards by the lever provided until the filament was brought into focus, and brought to the center of the field of view by the two lamp centering screws.

The lamp was moved outwards or inwards until the field was even illuminated. If the light beam was not directed exially into the condenser, the track would be twisted. The subsidiary condenser lens in the base of the instrument was used to ensure even illumination with the lower power objectives. It was done by sliding it behind the window in the base by means of the lever on the left.

The two eyepiece tubes can be varied by sliding the adjustment inwards or out-wards for the comfort of the observer.

II.4 <u>Procedure</u>.

The plate was scanned by placing upon the stage of the microscope that can be moved along two mutually perpendicular directions, the X - and Y - directions. The stage motion is facilitated by means of two screw gauges which give the distance travelled in each direction.

The way to move the plate to right and left along the axis is called X-axis and perpendicular to this direction is called Y - axis. The coordinates of events X and Y were recorded to avoid repeating the same events more than once. The image of big stars were sketched and the number of 2 prong stars, 3 prong stars to 5 prong star were counted.

The scanning area in each plate which was exposed in the other places was 4 x 5 square centimeters. As the nuclear emulsion plate was bigger than the movement of the stage, the plate was divided into four areas. All stars from each area were counted in order to find the star rate in stars per c.c. per day.

The star rate can be calculated by using:

The difference between the number of stars in two plates which was exposed and developed on the same day from each place and the numbers of stars in two plates from background divided by the number of plates, multiplied by scanned area (4 cm. x 5 cm.) and the thickness of nuclear emulsion on the plate (300×10^{-4} cm.) and the number of days which the plates were exposed (8 January - 25 February) and (6 Jan. - 10 April). The results are shown in table II, III, IV and V respectively. The errors shown are standard errors and can be calculated ~~from~~: as followed.

Let N be the number of stars which occur in a volume V c.c. of an emulsion exposed in t days

$$\text{Star rate} = \frac{N}{v \times t} \quad \text{stars / c.c. / day}$$

$$\text{Error of star rate} = \pm \frac{\sqrt{N}}{v \times t} \quad \text{star / c.c. / day.}$$

Table II Frequency distribution of stars at Wat Suan Dok(313 m. altitude)

No.of prongs per star	No.of stars			Star rates in star/c.c/day		Mean
	8 Jan. 1963	25Feb. 1963*	10Apr. 1963	8Jan.-25Feb.*	8Jan.-10April	
2	188		595		3.68 ± 0.18	3.68 ± 0.18
3	684		2031		12.07 ± 0.33	12.07 ± 0.33
4	332		1161		7.51 ± 0.26	7.51 ± 0.26
5	72		176		0.94 ± 0.09	0.94 ± 0.09
6	6		16		0.09 ± 0.03	0.09 ± 0.03
7	5		3		-0.02 ± 0.01	-0.02 ± 0.01
8	1		5		0.04 ± 0.02	0.04 ± 0.02
9	2		4		0.02 ± 0.01	0.02 ± 0.01
10	3		1		-0.02 ± 0.01	-0.02 ± 0.01
11	1		-		-0.01 ± 0.01	-0.01 ± 0.01
12	-		2		0.01 ± 0.01	0.02 ± 0.01
13	1		1		-	-
14	-		1		0.02 ± 0.01	0.01 ± 0.01
15					0	

Total rate of production of stars = 24.41 ± 0.47 stars/c.c/day

The rate of production of stars > 2 prongs = 20.1 ± 0.48 "

The rate of production of stars > 5 prong = 0.118 ± 0.03 "

*plates were damaged during exposure

Table III Frequency distribution of stars at Doi Suthep (altitude 1,650 m.)

No. of prongs per star	No. of stars 8Jan. 1963*	25Feb 1963	10Apr.* 1963	Star rates in star/c.c/day 8Jan.-10April	8Jan.-10April*	Mean
2	188	332		2.50 ± 0.21		2.50 ± 0.21
3	684	1122		7.61 ± 0.36		7.61 ± 0.36
4	332	608		4.79 ± 0.29		4.79 ± 0.29
5	72	149		1.34 ± 0.15		1.34 ± 0.15
6	6	11		0.09 ± 0.04		0.09 ± 0.04
7	5	3		-0.03 ± 0.02		-0.03 ± 0.02
8	1	5		0.07 ± 0.03		0.07 ± 0.03
9	2	4		0.03 ± 0.02		0.09 ± 0.02
10	3	3		-		-
11	1	1		-		-
12	-	1		0.02 ± 0.02		0.02 ± 0.02
13	1	1		-		-
14	-	1		0.02 ± 0.02		0.02 ± 0.02
15						

Total rate of production of stars = 16.21 ± 0.52 stars/c.c/day

The rate of production of stars > 2 prongs = 13.62±0.48 "

The rate of production of stars > 5 prongs = 0.17±0.05 "

* plates were damaged during exposure

Table IV Frequency distribution of stars at Doi Intanone (altitude 2,000 m.)

No. of prongs per star	No. of stars			Star rates in star/c.c/day		Mean
	8 Jan. 1963	25 Feb 1963	10 April 1963	8 Jan.-25 Feb.	8 Jan.-10 April	
2	188	295	525	1.86 ± 0.18	3.05 ± 0.17	2.42 ± 0.24
3	684	858	1751	3.02 ± 0.22	9.65 ± 0.30	6.26 ± 0.37
4	532	461	982	3.02 ± 0.23	5.83 ± 0.23	4.01 ± 0.30
5	72	121	222	0.85 ± 0.12	1.24 ± 0.10	1.09 ± 0.16
6	6	10	16	0.07 ± 0.03	0.09 ± 0.03	0.08 ± 0.01
7	5	9	13	0.07 ± 0.03	0.07 ± 0.03	0.07 ± 0.01
8	1	5	12	0.07 ± 0.03	0.10 ± 0.03	0.03 ± 0.01
9	2	2	6	-	0.05 ± 0.02	0.03 ± 0.02
10	3	2	1	-0.02 ± 0.02	-	-0.01 ± 0.02
11	1	1	1	-	-	-
12	-	1	3	0.02 ± 0.02	0.03 ± 0.02	0.02 ± 0.02
13	1	-	3	-0.02 ± 0.02	0.02 ± 0.01	0.02 ± 0.02
14	-	1	1	-0.02 ± 0.02	0.01 ± 0.01	0.01 ± 0.02
15	-	1	-	0.02 ± 0.02		0.01 ± 0.02

Total rate of production of stars = 14.16 ± 0.57 stars/c.c/day

The rate of production of stars > 2 prongs = 11.71 ± 0.51 "

The rate of production of stars > 5 prongs = 0.27 ± 0.08 "

Table V Frequency distribution of star at Doi Intanone ((2,595 m. altitude))

No.of prongs per star	No. of stars 8Jan. 1963	25Feb 1963	10April 1963	Star rates in star/c.c/day 8Jan.-25Feb.	8Jan.-10April	Mean
2	188	290	505	1.77 ± 0.18	2.87 ± 0.16	2.29 ± 0.24
3	684	825	1716	2.45 ± 0.21	9.35 ± 0.29	5.82 ± 0.37
4	332	428	920	1.67 ± 0.17	5.32 ± 0.22	3.45 ± 0.27
5	72	134	299	1.08 ± 0.15	2.06 ± 0.15	1.54 ± 0.19
6	6	19	25	0.23 ± 0.06	0.17 ± 0.04	0.20 ± 0.07
7	5	10	13	0.09 ± 0.04	0.07 ± 0.03	0.08 ± 0.05
8	1	8	13	0.12 ± 0.05	0.11 ± 0.03	0.11 ± 0.06
9	2	6	12	0.07 ± 0.03	0.09 ± 0.03	0.08 ± 0.04
10	3	3	9	-	0.05 ± 0.02	0.03 ± 0.02
11	1	1	7	-	0.05 ± 0.02	0.03 ± 0.02
12	-	2	3	0.03 ± 0.02	0.03 ± 0.02	0.03 ± 0.03
13	1	1	1	-	-	-
14	-	-	-	-	-	-
15	-	-	1	-	0.01 ± 0.01	0.01 ± 0.01

Total rate of production of stars = 13.75 ± 0.55 stars/c.c/day

The rate of production of stars > 2 prongs = 11.45 ± 0.50 "

The rate of production of stars > 5 prongs = 0.56 ± 0.11 "

Table VI Comparison of star rates per numbers of prongs per star between Wat Suan Dok, Doi Suthep and Doi Intanone.

No. of prongs per star	Star rate per c.c. per day		
	Wat Suan Dok 313 m.	Doi Suthep 1,650 m.	Doi Intanone 2,595 m.
> 2	20.1 ± 0.470	13.62 ± 0.482	11.45 ± 0.504
> 3	8.57 ± 0.278	6.16 ± 0.322	5.75 ± 0.359
> 4	1.06 ± 0.098	1.48 ± 0.150	2.11 ± 0.225
> 5	0.118 ± 0.033	0.17 ± 0.054	0.56 ± 0.11
> 6	0.027 ± 0.017	0.085 ± 0.038	0.44 ± 0.11
Total	24.41 ± 0.47	16.21 ± 0.523	13.78 ± 0.551