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Shri Gouriyo Baishnab Abhidhan and the Graphical Law

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Abstract

We study the entries of the dictionary, Shri Gouriyo Baishnab Abhidhan, compiled by Shri Haridas Das, the first edition. We draw the natural logarithm of the number of entries, normalised, starting with a letter vs the natural logarithm of the rank of the letter, normalised. We conclude that the dictionary can be characterised by BW(c=0), the magnetisation curve of the Ising Model in the Bragg-Williams approximation in the absence of external magnetic field, H. $c=\frac{H}{\gamma\varepsilon}=0$ with ε being the strength of coupling between two neighbouring spins in the Ising Model, γ representing the number of nearest neighbours of a spin, which is very large.

Keywords: Gouriyo Baishnab Abhidhan, Dictionary, Ranking, Magnetisation, Ising Model, Bragg-Williams approximation.

Introduction

"Bhajo Gourangya, japo Gourangya, laho Gourangya-r nam re....,"

singing as the ballad singer approaches, adding to the silence, in the wee hours of morning, from far, a son and the Sun realises it's time to leave the bed.

The Gouriyo Baishnab is a Baishanbite sect of Hindu religion, with the main center at Nabadwip, in the outskirts of Kolkata, in West Bengal, in India. Thinking a spin glass magnetisation curve underlying the dictionary of that sect, we go over and study Shri Gouriyo Baishnab Abhidhan compiled by Shri Haridas Das, the first edition, [1]. Though partly spin glass nature appears, the overall nature of the dictionary is BW(c=0), the magnetisation curve of the Ising Model in the Bragg-Williams approximation in the absence of external magnetic field, H. $c=\frac{H}{\gamma\varepsilon}=0$ with ε being the strength of coupling between two neighbouring spins in the Ising Model, γ representing the number of nearest neighbours of a spin, which is very large. It will be interesting to follow up this work, counting only the head words.

This is an interesting dictionary, [1], with elucidation of many Hindu mythological terms. We count one by one all words of this dictionary. Ironically, page 1 and page 2 are missing from the copy we have used. We take the local average number of words per page, thirteen, for this two pages. Similarly for pages 911, 912 which are missing, we take the number of words per page as thirty. The result is the table, Table1.

Table 1: Shri Gouriyo Baishnab Abhidhan: the odd rows represent letters of the Bengali alphabet, in the serial order; the even rows represent the respective number of entries of, [1].

a	**á**	**i**	**í**	**u**	**ú**	**ṛi**	**ṛṛi**	**li**	**lili**
3015	866	163	69	887	63	55	2	2	1
e	ei	o	ou	ka	kha	ga	gha	gna	cha
119	41	27	85	1945	139	742	94	2	626
chha	ja	jha	nya	ṭa	ṭha	ḍa	ḍha	ṇa	ta
72	450	30	3	9	3	28	10	5	792
tha	da	dha	na	pa	pha	ba	bha	ma	ya
3	977	318	1264	2961	81	481	813	1503	454
ra	la	ba	sha	ṣha	sa	ha			
705	367	2512	1138	81	2953	480			

To visualise we plot the number of words against the respective letters in the dictionary sequence, [1], in the adjoining figure, Figure 1.

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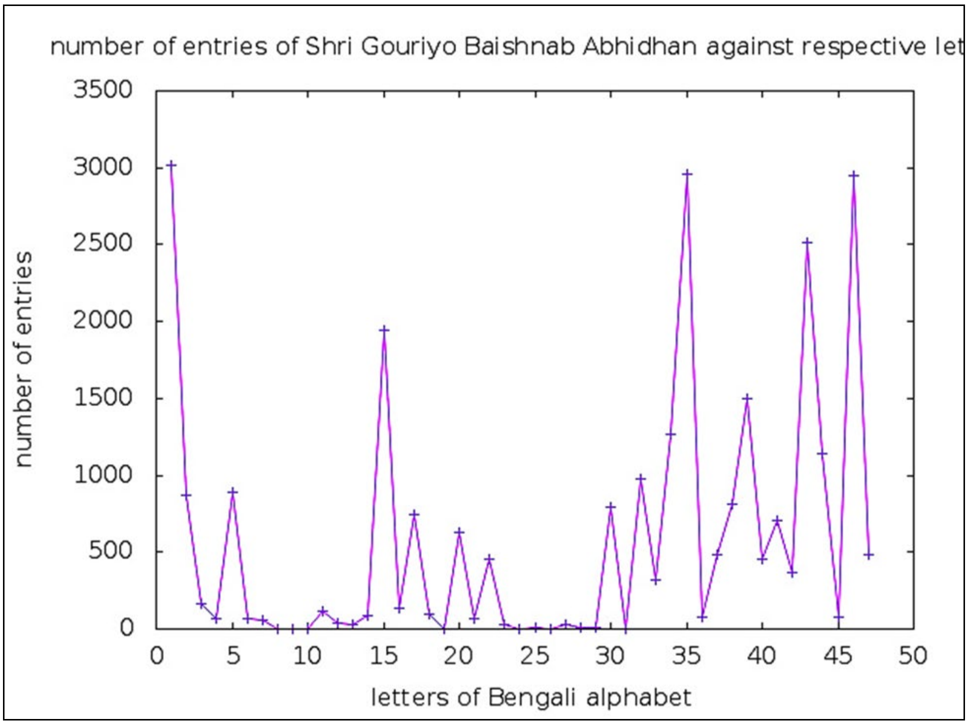

Fig 1: The vertical axis is the number of the words of Shri Gouriyo Baishnab Abhidhan, [1]. The horizontal axis is the letters of the Bengali alphabet. Letters are represented by the sequence number in the alphabet as it appears in the dictionary, [1].

Next we look for the graphical law. We have started considering magnetic field pattern in [2], in the languages we converse with. We have studied there, a set of natural languages, [2], and have found existence of a magnetisation curve under each language. We have termed this phenomenon as the Graphical Law. Then, we moved on to investigate, [3], into dictionaries of five disciplines of knowledge and found the existence of a curve of magnetisation under each discipline. This was followed by finding of the graphical law in the references from [4] to [108].

The planning of the paper is as follows. In the next section, we describe the Graphical Law analysis of the words of Shri Gouriyo Baishnab Abhidhan, [1]. In the section III, we give an introduction to the standard curves of magnetisation of Ising model. The section IV is Acknowledgment. The last section is Bibliography.

The Graphical Law Analysis

For the purpose of exploring graphical law, we assort the letters according to the number of entries, in the descending order, denoted by f and the respective rank, denoted by k. k is a positive integer starting from one. The lowest value of f is one. The corresponding rank, k, denoted as k_{lim} is forty two. As a result both $\frac{lnf}{lnf_{max}}$ and $\frac{lnk}{lnk_{lim}}$ varies from zero to one. Then we tabulate in the adjoining table, Table-2, and plot $\frac{lnf}{lnf_{max}}$ against $\frac{lnk}{lnk_{lim}}$ in the figure, Figure 2. We then ignore the letter with the highest number of entries starting with, tabulate in the adjoining table, Table-2, and redo the plot, normalising the lnf s with next-to-maximum $lnf_{n\text{-}max}$, and starting from k=2 in the figure, Figure3. This program then we repeat up to k=7, resulting in the figures up to Figure 9.

Table 2: Shri Gouriyo Baishnab Abhidhan entries: ranking, natural logarithm, normalization.

k	lnk	$\frac{lnk}{lnk_{lim}}$	f	lnf	$\frac{lnf}{lnf_{max}}$	$\frac{lnf}{lnf_{nmax}}$	$\frac{lnf}{lnf_{2nmax}}$	$\frac{lnf}{lnf_{3nmax}}$	$\frac{lnf}{lnf_{4nmax}}$	$\frac{lnf}{lnf_{5nmax}}$	$\frac{lnf}{lnf_{6nmax}}$	$\frac{lnf}{lnf_{7nmax}}$
1	0	0	3015	8.011	1	Blank	Blank	Blank	Blank	Blank	Blank	Blank
2	0.69	0.184	2961	7.993	0.998	1	Blank	Blank	Blank	Blank	Blank	Blank
3	1.10	0.294	2953	7.991	0.998	0.9997	1	Blank	Blank	Blank	Blank	Blank
4	1.39	0.372	2512	7.829	0.977	0.979	0.980	1	Blank	Blank	Blank	Blank
5	1.61	0.430	1945	7.573	0.945	0.947	0.948	0.967	1	Blank	Blank	Blank
6	1.79	0.479	1503	7.315	0.913	0.915	0.915	0.934	0.966	1	Blank	Blank
7	1.95	0.521	1264	7.142	0.892	0.894	0.894	0.912	0.943	0.976	1	Blank
8	2.08	0.556	1138	7.037	0.878	0.880	0.881	0.899	0.929	0.962	0.985	1
9	2.20	0.588	977	6.884	0.859	0.861	0.861	0.879	0.909	0.941	0.964	0.978
10	2.30	0.615	887	6.788	0.847	0.849	0.849	0.867	0.896	0.928	0.950	0.965
11	2.40	0.642	866	6.764	0.844	0.846	0.846	0.864	0.893	0.925	0.947	0.961
12	2.48	0.663	813	6.701	0.836	0.838	0.839	0.856	0.885	0.916	0.938	0.952

13	2.56	0.684	792	6.675	0.833	0.835	0.835	0.853	0.881	0.913	0.935	0.949
14	2.64	0.706	742	6.609	0.825	0.827	0.827	0.844	0.873	0.903	0.925	0.939
15	2.71	0.725	705	6.558	0.819	0.820	0.821	0.838	0.866	0.897	0.918	0.932
16	2.77	0.741	626	6.439	0.804	0.806	0.806	0.822	0.850	0.880	0.902	0.915
17	2.83	0.757	481	6.176	0.771	0.773	0.773	0.789	0.816	0.844	0.865	0.878
18	2.89	0.773	480	6.174	0.771	0.772	0.773	0.789	0.815	0.844	0.864	0.877
19	2.94	0.786	454	6.118	0.764	0.765	0.766	0.781	0.808	0.836	0.857	0.869
20	3.00	0.802	450	6.109	0.763	0.764	0.764	0.780	0.807	0.835	0.855	0.868
21	3.04	0.813	367	5.905	0.737	0.739	0.739	0.754	0.780	0.807	0.827	0.839
22	3.09	0.826	318	5.762	0.719	0.721	0.721	0.736	0.761	0.788	0.807	0.819
23	3.14	0.840	163	5.094	0.636	0.637	0.637	0.651	0.673	0.696	0.713	0.724
24	3.18	0.850	139	4.934	0.616	0.617	0.617	0.630	0.652	0.675	0.691	0.701
25	3.22	0.861	119	4.779	0.597	0.598	0.598	0.610	0.631	0.653	0.669	0.679
26	3.26	0.872	94	4.543	0.567	0.568	0.569	0.580	0.600	0.621	0.636	0.646
27	3.30	0.882	85	4.443	0.555	0.556	0.556	0.568	0.587	0.607	0.622	0.631
28	3.33	0.890	81	4.394	0.548	0.550	0.550	0.561	0.580	0.601	0.615	0.624
29	3.37	0.901	72	4.277	0.534	0.535	0.535	0.546	0.565	0.585	0.599	0.608
30	3.40	0.909	69	4.234	0.529	0.530	0.530	0.541	0.559	0.579	0.593	0.602
31	3.43	0.917	63	4.143	0.517	0.518	0.518	0.529	0.547	0.566	0.580	0.589
32	3.47	0.928	55	4.007	0.500	0.501	0.501	0.512	0.529	0.548	0.561	0.569
33	3.50	0.936	41	3.714	0.464	0.465	0.465	0.474	0.490	0.508	0.520	0.528
34	3.53	0.944	30	3.401	0.425	0.425	0.426	0.434	0.449	0.465	0.476	0.483
35	3.56	0.952	28	3.332	0.416	0.417	0.417	0.426	0.440	0.456	0.467	0.473
36	3.58	0.957	27	3.296	0.411	0.412	0.412	0.421	0.435	0.451	0.461	0.468
37	3.61	0.965	10	2.303	0.287	0.288	0.288	0.294	0.304	0.315	0.322	0.327
38	3.64	0.973	9	2.197	0.274	0.275	0.275	0.281	0.290	0.300	0.308	0.312
39	3.66	0.979	5	1.609	0.201	0.201	0.201	0.206	0.212	0.220	0.225	0.229
40	3.69	0.987	3	1.099	0.137	0.137	0.138	0.140	0.145	0.150	0.154	0.156
41	3.71	0.992	2	0.693	0.087	0.087	0.087	0.089	0.092	0.095	0.097	0.098
42	3.74	1	1	0	0	0	0	0	0	0	0	0

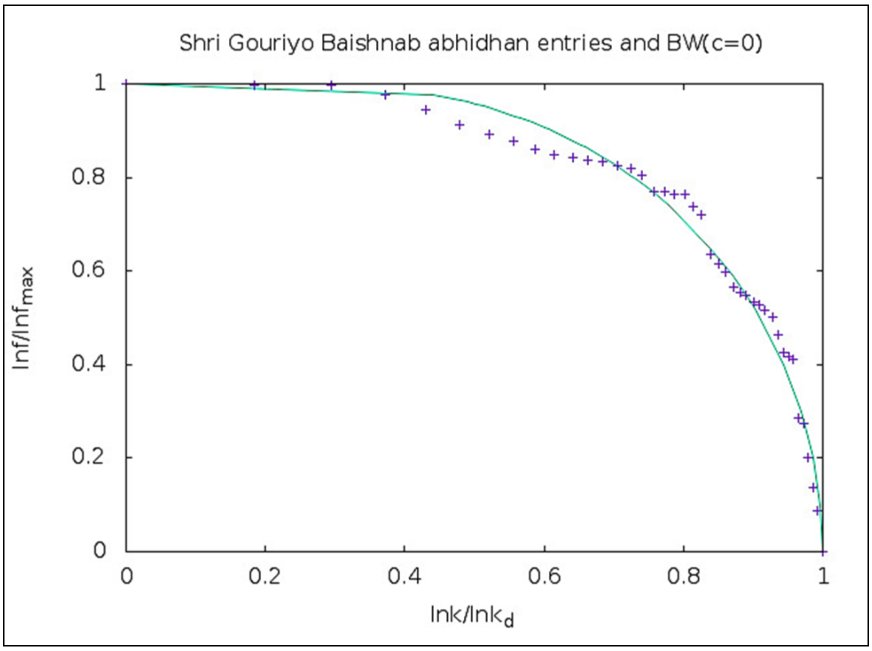

Fig 2: The vertical axis is $\frac{\ln f}{\ln f_{max}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$. The + points represent the entries of Shri Gouriyo Baishnab Abhidhan, with the fit curve, BW(c=0), being the Bragg-Williams curve in the absence of external magnetic field, c=$\frac{H}{\gamma\varepsilon}$ =0.

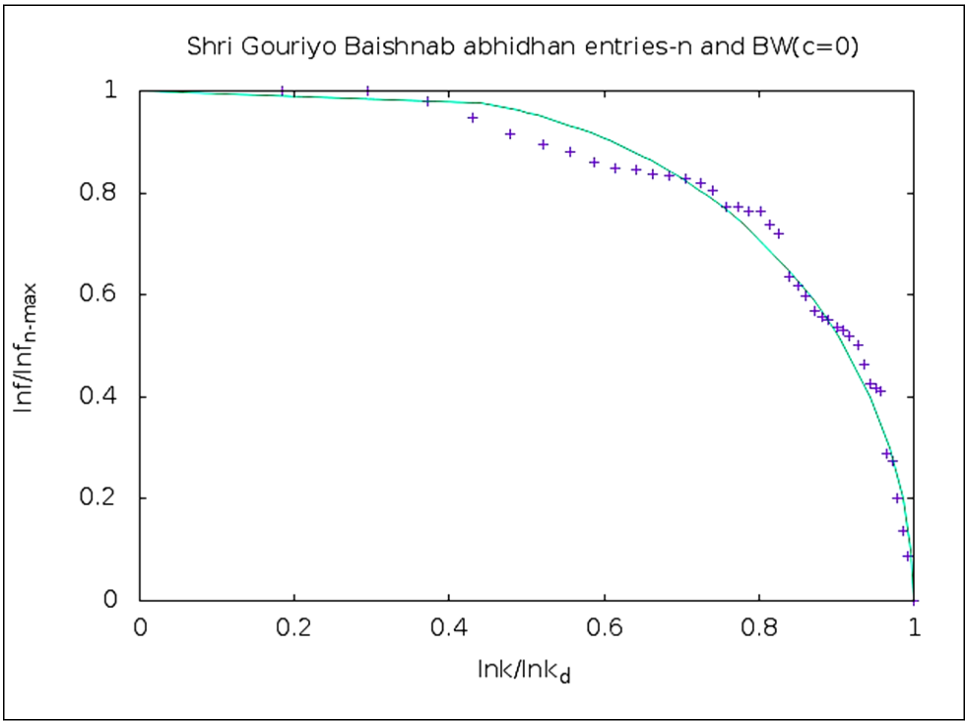

Fig 3: The vertical axis is $\frac{\ln f}{\ln f_{nmax}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$. The + points represent the entries of Shri Gouriyo Baishnab Abhidhan, with the fit curve, BW(c=0), being the Bragg-Williams curve in the absence of external magnetic field, c=$\frac{H}{\gamma\varepsilon}$ =0.

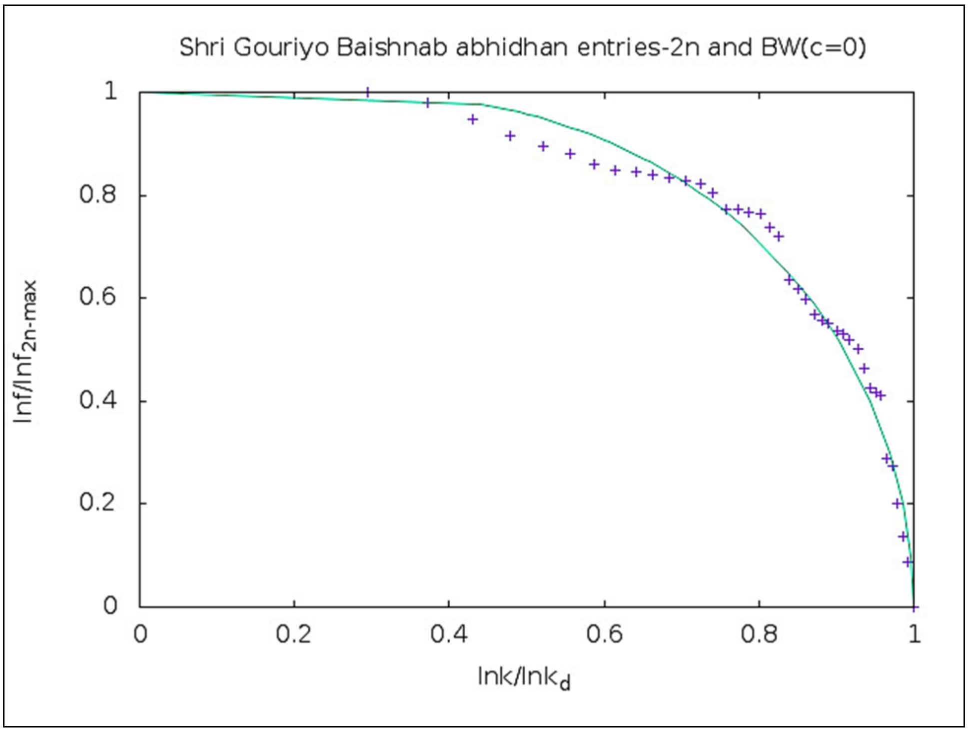

Fig 4: The vertical axis is $\frac{\ln f}{\ln f_{2nmax}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$. The + points represent the entries of Shri Gouriyo Baishnab Abhidhan, with the fit curve, BW(c=0), being the Bragg-Williams curve in the absence of external magnetic field, c=$\frac{H}{\gamma\varepsilon}$ =0.

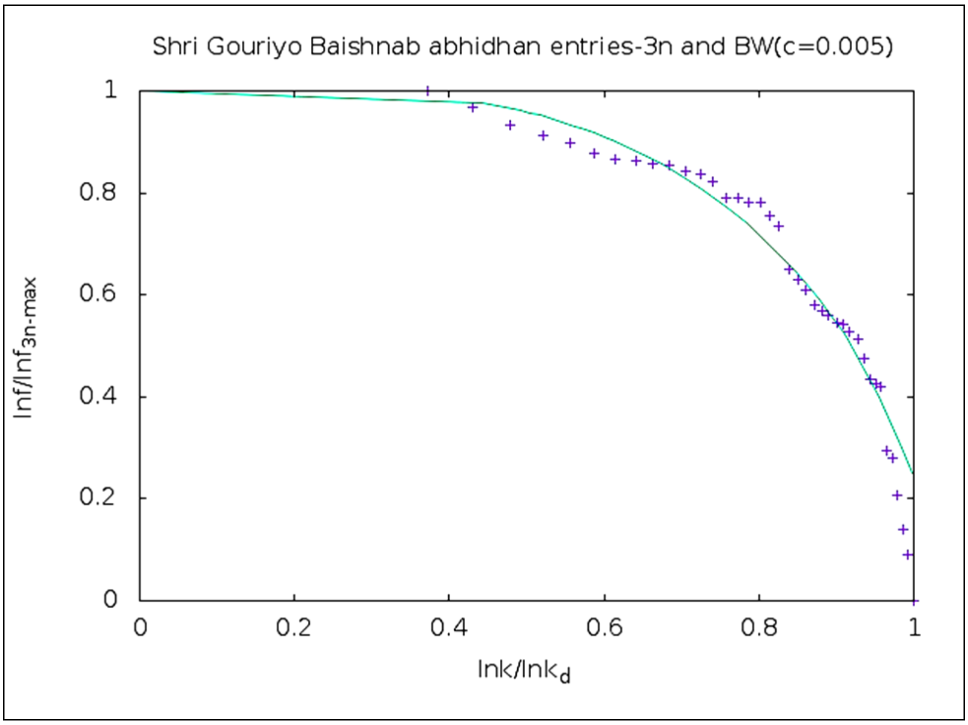

Fig 5: The vertical axis is $\frac{lnf}{ln f_{3nmax}}$ and the horizontal axis is $\frac{lnk}{\ln k_{lim}}$. The + points represent the entries of Shri Gouriyo Baishnab Abhidhan, with the fit curve, BW(c=0.005), being the Bragg-Williams curve in the presence of external magnetic field, c=$\frac{H}{\gamma\varepsilon}$=0.005.

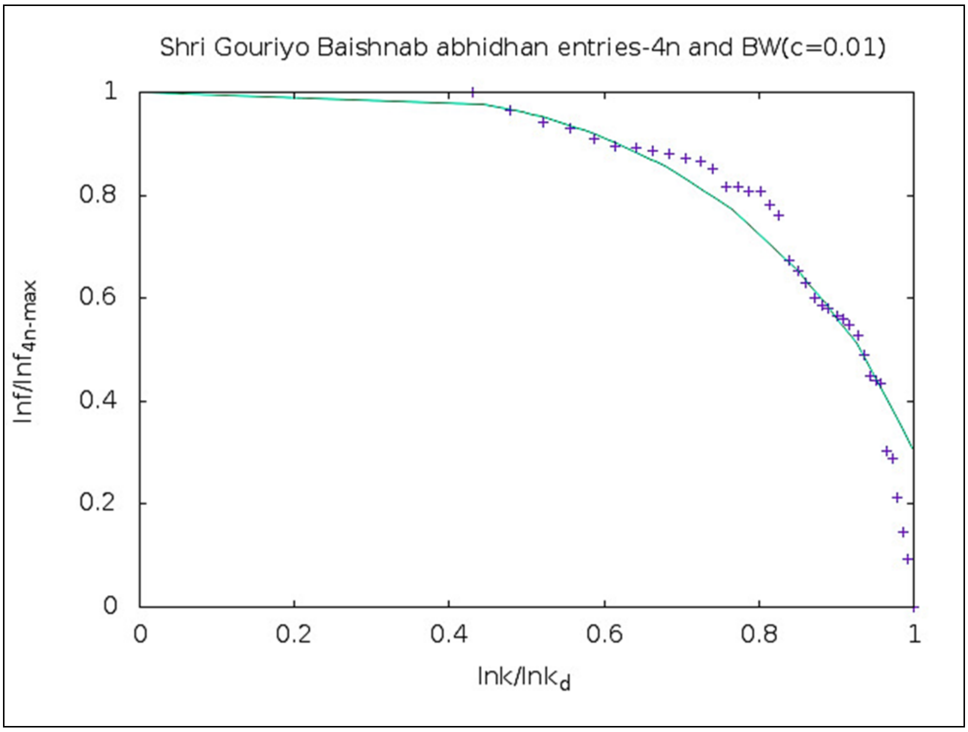

Fig 6: The vertical axis is $\frac{lnf}{ln f_{4nmax}}$ and the horizontal axis is $\frac{lnk}{\ln k_{lim}}$. The + points represent the entries of Shri Gouriyo Baishnab Abhidhan, with the fit curve, BW(c=0.01), being the Bragg-Williams curve in the presence of external magnetic field, c=$\frac{H}{\gamma\varepsilon}$=0.01.

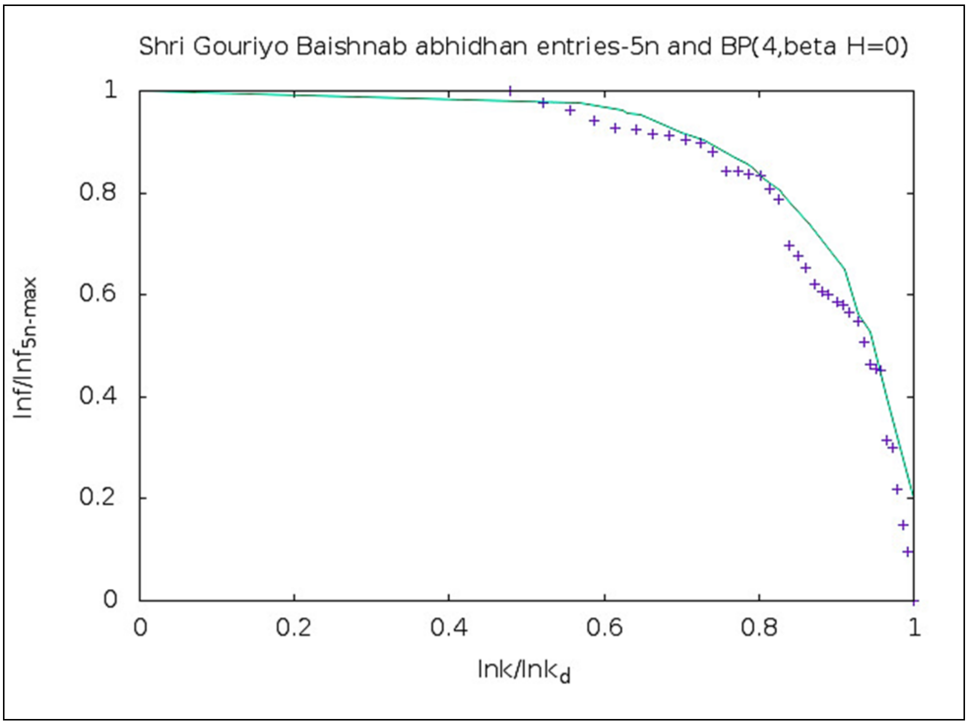

Fig 7: The vertical axis is $\frac{\ln f}{\ln f_{5nmax}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$. The + points represent the entries of Shri Gouriyo Baishnab Abhidhan, with the fit curve being the Bethe-Peierls curve, BP(4, βH=0), of the Ising Model, in the presence of four nearest neighbours and in the absence of external magnetic field, H= 0.

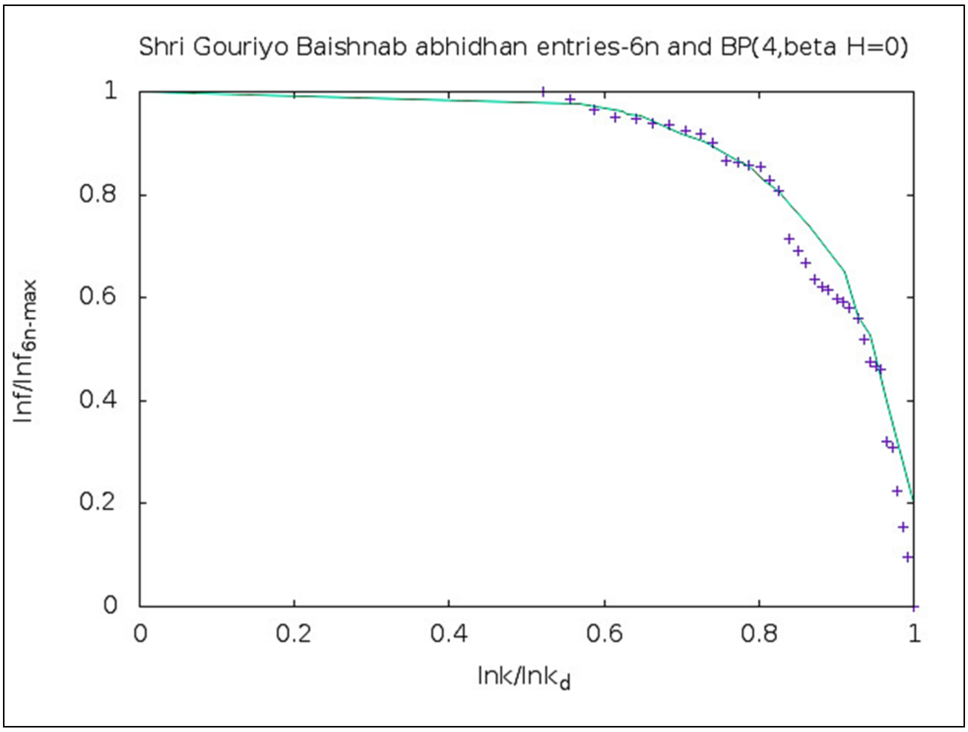

Fig 8: The vertical axis is $\frac{\ln f}{\ln f_{6nmax}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$. The + points represent the entries of Shri Gouriyo Baishnab Abhidhan, with the fit curve being the Bethe-Peierls curve, BP(4, βH=0), of the Ising Model, in the presence of four nearest neighbours and in the absence of external magnetic field, H= 0.

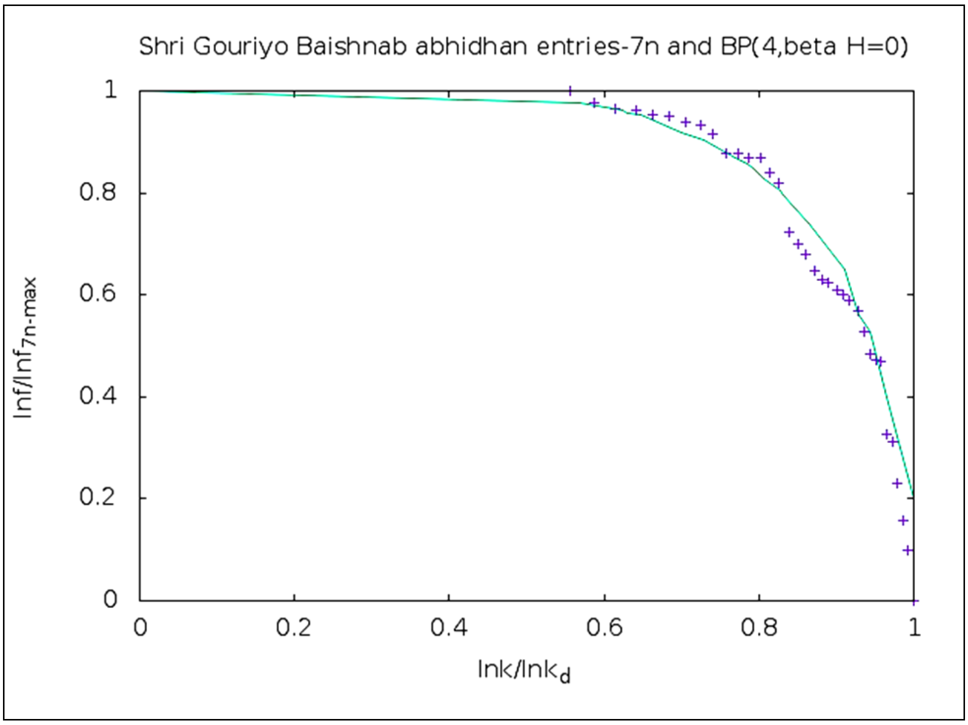

Fig 9: The vertical axis is $\frac{\ln f}{\ln f_{7nmax}}$ and the horizontal axis is $\frac{\ln k}{\ln k_{lim}}$. The + points represent the entries of Shri Gouriyo Baishnab Abhidhan, with the fit curve being the Bethe-Peierls curve, BP(4, βH=0), of the Ising Model, in the presence of four nearest neighbours and in the absence of external magnetic field, H= 0.

Conclusion

From the figures, Figure2-Figure9, we observe that there is a curve of magnetisation, behind the entries of Shri Gouriyo Baishnab Abhidhan, [1]. This is the magnetisation curve, BW(c=0), in the Bragg-Williams approximation of the Ising model, in the absence of external magnetic field, H, with $c=\frac{H}{\gamma\epsilon}=0$.

Moreover, the associated correspondence is,

$$\frac{\ln f}{\ln f_{max}} \leftrightarrow \frac{M}{M_{max}} \text{ and } \ln k \leftrightarrow T,$$

k corresponds to temperature in an exponential scale, [116].

Magnetisation

Bragg-Williams Approximation

Let us consider a coin. Let us toss it many times. Probability of getting head or, tale is half i.e. we will get head and tale equal number of times. If we attach value one to head, minus one to tale, the average value we obtain, after many tossing is zero. Instead let us consider a one-sided loaded coin, say on the head side. The probability of getting head is more than one half, getting tale is less than one-half. Average value, in this case, after many tossing we obtain is non-zero, the precise number depends on the loading. The loaded coin is like ferromagnet, the unloaded coin is like paramagnet, at zero external magnetic field. Average value we obtain is like magnetisation, loading is like coupling among the spins of the ferromagnetic units. Outcome of single coin toss is random, but average value we get after long sequence of tossing is fixed. This is long-range order. But if we take a small sequence of tossing, say, three consecutive tossing, the average value we obtain is not fixed, can be anything. There is no short-range order.

Let us consider a row of spins, one can imagine them as spears which can be vertically up or, down. Assume there is a long-range order with probability to get a spin up is two third. That would mean when we consider a long sequence of spins, two third of those are with spin up. Moreover, assign with each up spin a value one and a down spin a value minus one. Then total spin we obtain is one third. This value is referred to as the value of long-range order parameter.

Now consider a short-range order existing which is identical with the long-range order. That would mean if we pick up any three consecutive spins, two will be up, one down. Bragg-Williams approximation means short-range order is identical with long-range order, applied to a lattice of spins, in general. Row of spins is a lattice of one dimension.

Now let us imagine an arbitrary lattice, with each up spin assigned a value one and a down spin a value minus one, with an unspecified long-range order parameter defined as above by L = 1/N $\sum_i \sigma_i$ where, σ_i is i-th spin, N being total number of spins. L can vary from minus one to one. $N = N_+ + N_-$, where, N_+ is the number of up spins, N_- is the number of down spins. $L = \frac{1}{N}(N_+ - N_-)$. As a result, $N_+ = \frac{N}{2}(1 + L)$ and $N_- = \frac{N}{2}(1-L)$. Magnetisation or, net magnetic moment, M is $\mu\sum_i \sigma_i$ or, $\mu(N_+ - N_-)$ or, μNL, $M_{max} = \mu N$. $\frac{M}{M_{max}} = L$. $\frac{M}{M_{max}}$ is referred to as reduced magnetisation. Moreover, the Ising Hamiltonian, [110], for the lattice of spins, setting μ to one, is

$-\varepsilon\sum_{n.n}\sigma_i\,\sigma_j - H\sum_i\sigma_i$, where n.n refers to nearest neighbour pairs. The difference of energy, ΔE, if we flip an up spin to down spin is, [111], $2\varepsilon\gamma\bar{\sigma}+2H$, where γ is the number of nearest neighbours of a spin. According to Boltzmann principle $\frac{N_-}{N_+}$equals exp(− △E/k_B T), [112]. In the Bragg-Williams approximation, [113], $\bar{\sigma}$=L, considered in the thermal average sense. Consequently,

$$\ln\frac{1+L}{1-L} = 2\,(\gamma\varepsilon L+H)/(k_B\,T) = 2\,(L+H/\gamma\varepsilon)/(T/(\gamma\varepsilon/k_B))$$
$$=2(L+c)/(T/T_c)\ (1)$$

where, c = H/εγ. T_c = εγ/k_B, [114]. T/T_c is referred to as reduced temperature. Plot of L vs T/T_c or, reduced magentisation vs. reduced temperature is used as reference curve. In the presence of magnetic field, c ≠ 0, the curve bulges outward. Bragg-Williams is a Mean Field approximation. This approximation holds when number of neighbours interacting with a site is very large, reducing the importance of local fluctuation or, local order, making the long-range order or, average degree of freedom as the only degree of freedom of the lattice.

To have a feeling how this approximation leads to matching between experimental and Ising model prediction one can refer to FIGURE 12.12 of the book, [111]. W. L. Bragg was a professor of Hans Bethe. Rudlof Peierls was a friend of Hans Bethe. At the suggestion of W. L. Bragg, Rudlof Peierls following Hans Bethe improved the approximation scheme, applying quasi-chemical method.

Bethe-peierls Approximation in Presence of Four Nearest Neighbours, in Absence of External Magnetic Field:

In the approximation scheme which is improvement over the Bragg-Williams, [110], [111], [112], [113], [114], due to Bethe-Peierls [115], reduced magnetisation varies with reduced temperature, for γ neighbours, in absence of external magnetic field.

$$(\ln\gamma/(\gamma-2))/(\ln(\text{factor}-1)/D) = T/T_c \qquad (2)$$

Where, D=$factor^{((\gamma-1)/\gamma)}$-$factor^{(1/\gamma)}$ and factor =$(1+\frac{M}{M_{max}})/(1-\frac{M}{M_{max}})$. For γ=4 i.e. for four nearest neighbours, $\ln\frac{\gamma}{\gamma-2}$ is 0.693.

In the following, we describe datas generated from the Equation 1 and the Equation 2 in the table, Table-1, and curves of magnetisation plotted on the basis of those datas. BW stands for reduced temperature in Bragg-Williams approximation, calculated from the Equation 1. BP(4, βH=0) represents reduced temperature in the Bethe-Peierls approximation, for four nearest neighbours, computed from the Equation 2. The data set is used to plot Figure10. Empty spaces in the table, Table-3, mean corresponding point pairs were not used for plotting a line.

Table 3: Datas for Reduced temperature [for the Bragg-Williams approximation, in the absence (BW(c=0)) and in the presence (BW(c=0.005), BW(c=0.01)) of magnetic field, c=0, c=$\frac{H}{\gamma\varepsilon}$ =0.005, c=$\frac{H}{\gamma\varepsilon}$ =0.01 respectively and in the Bethe-Peierls approximation, BP(4, βH=0), in the absence of magnetic field, for four nearest neighbours] vs reduced magnetisation. Reduced temperature is drawn along the x-axis and Reduced magnetisation is drawn along the y-axis. In gnuplot the command is plot ". dat" using 1:2 with line; 1 standing for x-axis and 2 standing for y-axis datas.

BW(c=0)	BW(c=0.005)	BW(c=0.01)	BP(4, βH=0)	reduced magnetisation
0	0	0	0	1
0.435	0.437	0.439	0.563	0.978
0.439	0.441	0.443	0.568	0.977
0.491	0.493	0.495	0.624	0.961
0.501	0.504	0.507	0.630	0.957
0.514	0.517	0.519	0.648	0.952
0.559	0.562	0.565	0.654	0.931
0.566	0.569	0.573	0.7	0.927
0.584	0.587	0.590	0.7	0.917
0.601	0.604	0.607	0.722	0.907
0.607	0.610	0.613	0.729	0.903
0.653	0.658	0.661	0.770	0.869
0.659	0.663	0.666	0.773	0.865
0.669	0.674	0.678	0.784	0.856
0.679	0.684	0.688	0.792	0.847
0.701	0.705	0.709	0.807	0.828
0.723	0.728	0.732	0.828	0.805
0.732	0.736	0.743	0.832	0.796
0.753	0.758	0.766	0.845	0.772
0.779	0.784	0.788	0.864	0.740

0.838	0.844	0.853	0.911	0.651
0.850	0.858	0.864	0.911	0.628
0.870	0.877	0.885	0.923	0.592
0.883	0.891	0.899	0.928	0.564
0.899	0.908	0.918		0.527
0.905	0.914	0.926	0.941	0.513
0.944	0.956	0.968	0.965	0.400
		0.985		0.350
		0.998		0.310
0.969	0.985		0.965	0.300
	0.998			0.250
0.987			1	0.200
0.997			1	0.100
1			1	0

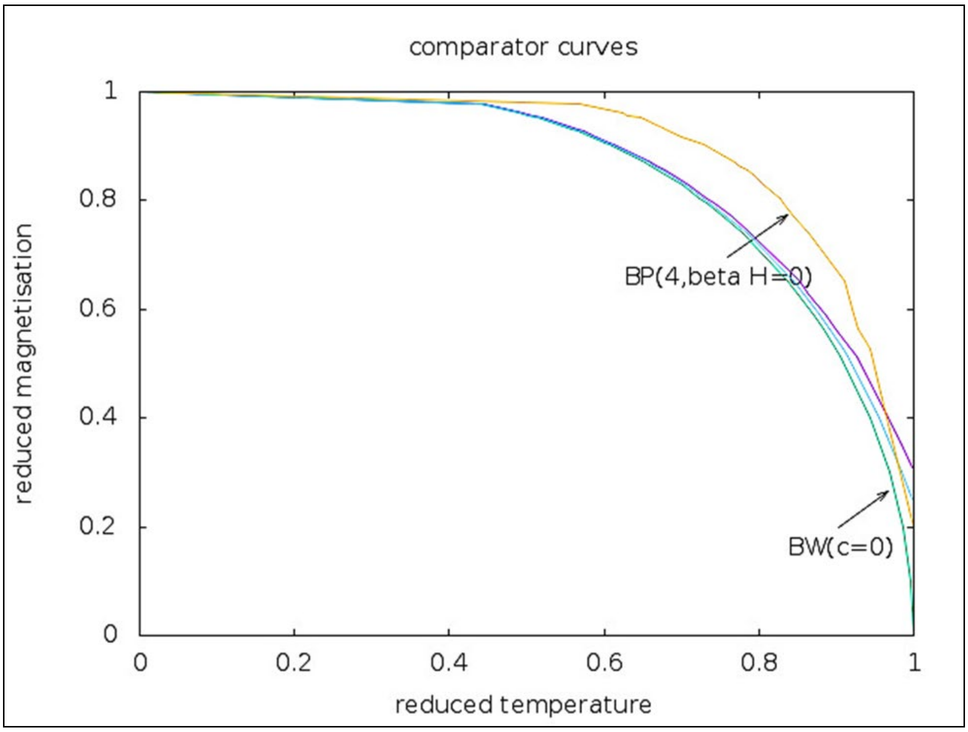

Fig 10: Reduced magnetisation vs reduced temperature curves, for the Bragg-Williams approximation, in the absence (BW(c=0)) and in the presence (BW(c=0.005), BW(c=0.01)) of magnetic field, $c=\frac{H}{\gamma\varepsilon}=0$, $c=\frac{H}{\gamma\varepsilon}=0.005$, $c=\frac{H}{\gamma\varepsilon}=0.01$, outwards; and in the Bethe-Peierls approximation, BP(4, βH=0), in the absence of magnetic field, for four nearest neighbours (outer in the top).

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