

Red Rain Cells of Kerala as a Possible Carrier of the Diffuse Interstellar Bands and the UV Extinction Bump

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Abstract Despite various proposals, no conclusive identification exists for the carriers of diffuse interstellar absorption bands DIBs and the UV extinction bump at 217.5 nm. The red rain cells of Kerala show strong absorption features near 216.5 nm and several weak absorption features in the wavelength region 400 to 900 nm which are superimposed on a broader blue-UV absorption peak. The red pigment extracted from the cells show strong peaks at 334 nm and 440 nm along with multitude of weak peaks. The measured absorption peaks are compared with that of DIBs and the UV bump. The higher peak widths for red cells in comparison with DIBs is attributed to the temperature difference between space environment and laboratory. Our results of the absorption spectra of red rain cells show significant correlation with the reported wavelengths of numerous DIBs and the UV extinction bump of the interstellar medium, thus showing that the red rain cells, which are of suspected extraterrestrial origin, is a plausible carrier of DIBs and the UV extinction bump.

Keywords: Diffuse interstellar bands, UV extinction bump, interstellar dust, red rain of Kerala

1 Introduction

The Diffuse Interstellar Bands (DIBs) and the ultraviolet extinction bump at 2175 Å are two unresolved spectroscopic puzzles of the interstellar medium (ISM). The other two mysterious spectroscopic features of the ISM are Extended Red Emission (ERE) and Unidentified Infrared bands (UIR). The DIBs are absorption lines detected in the spectra of stars that are obscured by interstellar clouds [1]. They are too broad to be associated with atomic lines and are observed in a spectral range extending from 4000 Å to 10000 Å exhibiting a strong diversity of profiles [2].

The identification of the carriers of the DIBs is one of the most challenging problems in astrophysics since the discovery of the first two such features [3]. The survey of Herbig [4] reported 39 DIBs. Since that time, the number of DIBs has been extended to more than 220 [5,6] and more than 250 DIBs are reported by Tuairisg et al. [7] with the highest density of bands found in the visible region (5400 - 6900 Å) [2,6]. Further, over 400 DIBs have been observed in the visible and near-infrared wavelength range in both the Milky Way and external galaxies, both nearby and distant [8]. The individual bands exhibit a wide variety of strengths and widths (full width at half maximum (FWHM) values for the DIBs range from about 0.6 to 40.0 Å).

A large number of surveys were initiated to understand the nature of the DIB carriers. It is now generally accepted that the DIBs are most likely due to free molecules in the gas phase [2], but so far there has been no definitive match between a subset of the diffuse bands and the gas-phase spectrum of any individual molecule. In a recent study, two DIBs were provisionally identified as due to fullerene C₆₀⁺ [9]. The current consensus is that the DIB carriers are most probably complex organic molecules in the neutral and/or ionized forms [10]. It has been suggested by many authors that these peaks arise from PAH structures, but objections raised initially by Schlemmer et al. [11] would still appear to be largely

valid. Moreover the formation of PAHs abiotically also poses problems [12], particularly because abiotic processes would not be expected to lead to the observed invariance of the characteristics of these bands.

The origin of the 217.5 nm absorption feature appearing in the interstellar extinction curve is a long-standing problem in astrophysics [13]. It is characterized by a stable position, but its band width changes according to the interstellar environment [14]. Many types of carbon and carbonaceous materials have been proposed to explain the 217 nm feature, including graphite [15], graphite spheres [16,17], hydrogenated amorphous carbon (HAC) [18], coal-like material [19], fullerenes [20], graphite onions [21]. An important contribution of a mixture of PAHs to the UV bump has been proposed by Joblin et al. [22]. Among the other proposed candidates are particles composed of silicate or graphite cores with a mantle of PAHs [23] and carbon onion particles [24,20]. All recent results point strongly toward a carbonaceous carrier for the UV bump. Alternative molecular explanations of the 2175 Å absorption, first proposed by Hoyle and Wickramasinghe in 1977, involve aromatic organic molecules [25]. The interstellar absorption feature at 2175 Å in stellar spectra could possibly be attributed to aromatic molecules within biological cells [12].

Here we show that the red cells which caused the red colour of the red rain of Kerala in 2001 are a possible candidate as a carrier of the DIBs and the UV extinction bump in the interstellar medium. The UV-visible-NIR absorption spectra of the red rain cells and its extracted red pigment in the range 190 to 900 nm can also be correlated with the spectra of DIBs and the UV extinction bump of ISM.

1.1 Evidences for Unusual Nature and Extraterrestrial Origin of Red Rain Cells

In an earlier paper we have argued that the red cells that caused the red rain of Kerala in 2001 are possibly of extraterrestrial origin [26]. These cells were proposed to have originated from fragments of a cometary meteor, which disintegrated in the upper atmosphere and it was argued that the red rain phenomenon is a possible case of Cometary Panspermia. At least 50,000 kg of these cells were estimated to have fallen in Kerala during July to September 2001 through various isolated red rain events which occurred at places separated by geographical distances of more than 400 km. It was also argued on the basis of spectro-fluorimetric study that the cells may not have DNA.

There are several cases of red rain events recorded in history which occurred in different parts of the world and it has been pointed out that many of these events have a correlation with meteoric falls [27]. In another study it was reported that IR spectrum of the red rain cells of Kerala was showing correlation with several unidentified IR emission bands of proto-planetary nebulae and it was commented that the cells could represent a completely unknown microorganism [28]. A study of the fluorescence properties of the cultured cells of these exotic microbes showed that they have an unusual kind of autofluorescence [29] which was interpreted as due to the possible presence of unidentified biomolecules. In a recent study we have argued that the red cells that caused the red rain of Kerala cannot be identified with Trentepohlia algal cells, because there are marked differences between red cells and Trentepohlia cells [30].

Reports of DNA detection using DAPI staining by Microscopic Probe technique after pigment removal by DMSO showed positive results [31]. Later we argued that the result of DAPI staining is not conclusive because of the continuous auto-fluorescence of the red cells, when its outer red pigment was removed [32]. The wide auto fluorescence behavior of the depigmented red cells has been described by Louis & Kumar [32] and Gangappa & Hogg [31]. Hence the blue fluorescence is not due to DNA rather due to autofluorescence of the red cells.

Using transmission electron microscopy, Gangappa et al. [33] demonstrated significant differences in the ultra-structure of red cells when compared with representative species from these groups. The red rain cells showed no evidence of typical eukaryotic internal structures such as mitochondria or endoplasmic reticulum. Also comparisons based on elemental composition using energy-dispersive X-ray analysis, as well as Raman spectral signatures demonstrate significant dissimilarities in their molecular composition and concluded that the identity and origins of the red rain cells remain an enigma [33].

Several episodes of red rain were also reported in the Central and Southern Provinces of Sri Lanka during late November and December 2012 [34]. The cause of the red coloration to the Sri Lankan red rain was due to huge quantity of red cells that had identical appearance to Kerala red rain cells. TEM and EDAX studies of the Sri Lankan red rain cells showed the outer cell wall unusually rich in uranium, and a nuclear region with a strong deficit or absence of phosphorus [34]. As phosphorus is present in DNA

structure as phosphate molecule, the absence of phosphorus in the cell interior can be suggestive evidence that the cell does not have DNA.

2 Experiments and Results

2.1 Broad Absorption Features of Red Rain Cells

In our previous study [26] we have reported the absorption spectra of the red cells in the uv-visible region which showed major absorption peaks at 200 nm , 505 nm and at 600 nm . Here the absorption spectra in the visible and near IR region have been analyzed more rigorously. The results of the UV-Visible absorption spectra of the red rain cells in the range 190 to 900 nm is shown in Fig. 1 for different red rainwater samples collected from various locations.

The concentrations of red cells suspended in the rainwater collected from different locations vary from sample to sample. Red cells collected from location 1 showed an absorption peak at 214.5 nm whereas the sample collected from location 2 showed an absorption peak at 213 nm and the sample collected from location 3 shows an absorption peak at 216.5 nm . This minor shift in the intensity peak is due to the red cells concentration. To study the concentration dependent absorption peak in the UV region, spectra were also recorded for diluted samples. The resultant spectra showed a peak shift towards lower wavelength region as concentration decreases. This result definitely does not fit with the absorption of most substances in solution, where a decrease in the absorption intensity is obtained as the concentration of the substance decreases. This contrary result observed in the red rain cells may be partly due to the clustering of the red cells in the sample. Particle clustering may strongly influence the absorption characteristics of nano-sized particles [35]. For a sample with highly concentrated red cells, the absorption peak was observed at 216.5 nm (sample collected from location 3, as indicated in the plot). A wavelength shift of about 1 nm between the laboratory sample and the interstellar material may be explained as due to the lower temperature of interstellar grains.

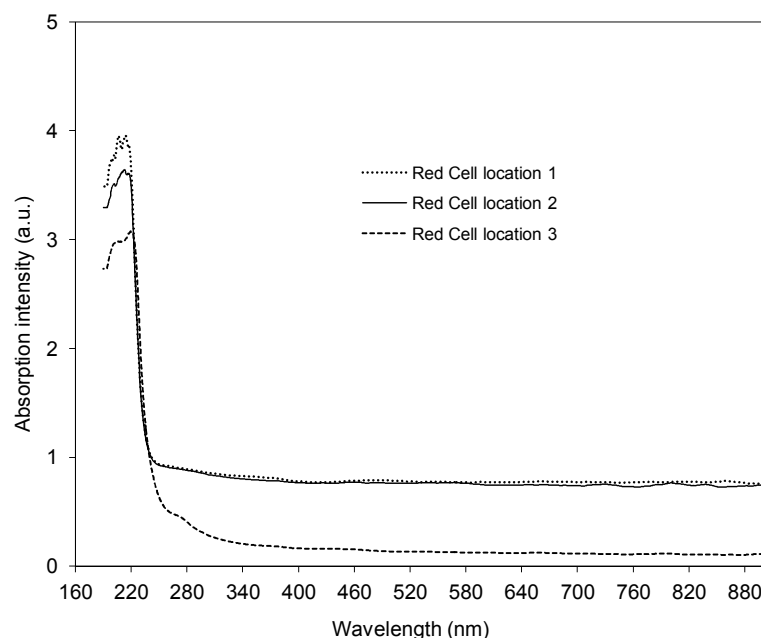


Figure 1: Absorption spectra of red cells for red rainwater samples collected from three different locations in Kerala, India during the 2001 red rain event.

2.2 Detailed Absorption Spectra of Red Rain Cells

The absorption spectra of the red rainwater collected from various locations showed several weak narrow absorption features in the visible and near IR region which are superimposed on a broader absorption peak. Since the absorption spectra of red cells show a large number of small peaks, the spectra are presented in two separate plots. The plot Fig. 2 (a) shows the absorption spectra of red cells in the wavelength range from 400 to 700 nm, whereas the plot Fig. 2 (b) shows the spectra in the region 700 to 900 nm. Spectra of the red cells in the wavelength range 400 - 700 nm showed 20 absorption peaks in which the strongest profile peaks were observed at 484.5 nm, 539 nm and 664 nm. In the wavelength region 700-900 nm the spectra of the sample shows another 20 peaks.

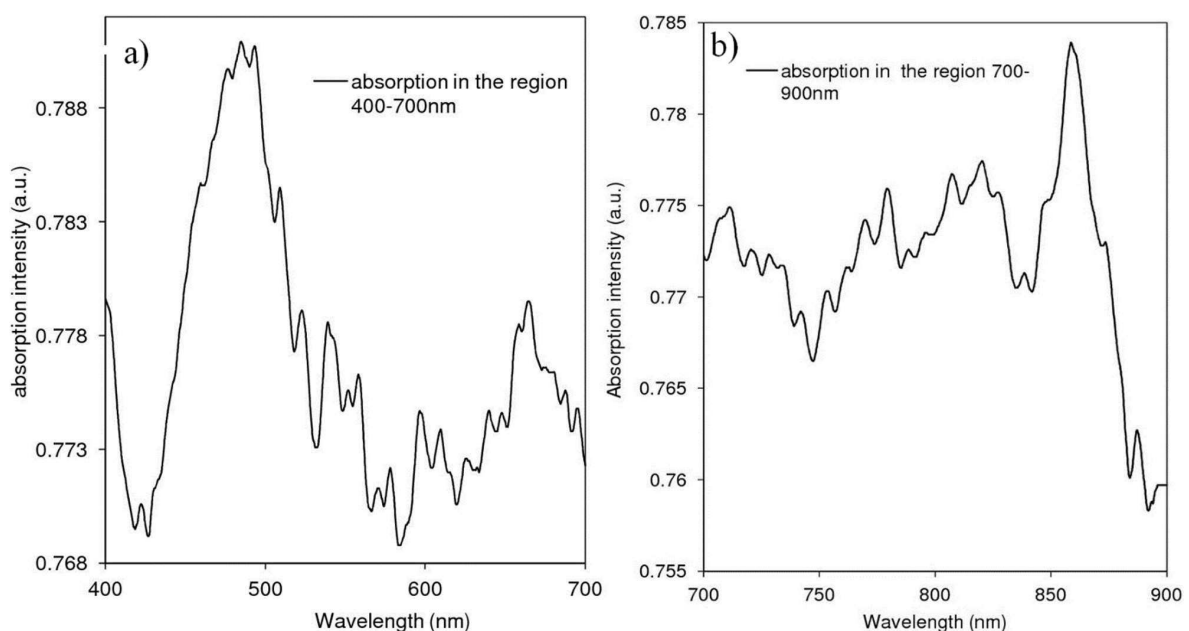


Figure 2: Detailed optical absorption spectra of the red rain cells of Kerala showing the weak absorption peaks : a) In the visible region from 400 - 700 nm, b) In the near IR region from 700 - 900 nm. Deconvoluted peaks are shown in Fig. 3. The measurements were made using UV Vis spectrophotometer (Jasco model V-650 and confirmed by Shimadzu spectrophotometer (model UV-2401 PC).

The spectra of red cell have been deconvoluted using a Gaussian deconvolution method and the resulting spectrum is shown in Fig. 3 for wavelength intervals of 100 nm (Fig. 3 (A)-(E)). The deconvoluted data are tabulated in Table 1 along with the peak position and corresponding bandwidth. The highest density of absorption peaks was observed in the region 500-700 nm, the strongest absorption peaks being at 639 nm, 483 nm, 518 nm and 540 nm. The other prominent peaks are observed at 826, 840, 767 and at 679 nm. The widths of these bands range from 16 to 24 nm, which are a factor of 10 higher than the widths of the DIBs. This may seem problem for our model at first sight, but the problem could be resolved if we note that the laboratory temperatures are about 10 times higher than the temperature of interstellar grains. With regard to central wavelength many of these peaks can be correlated with DIBs of the ISM with a wavelength deviation much below 1 nm.

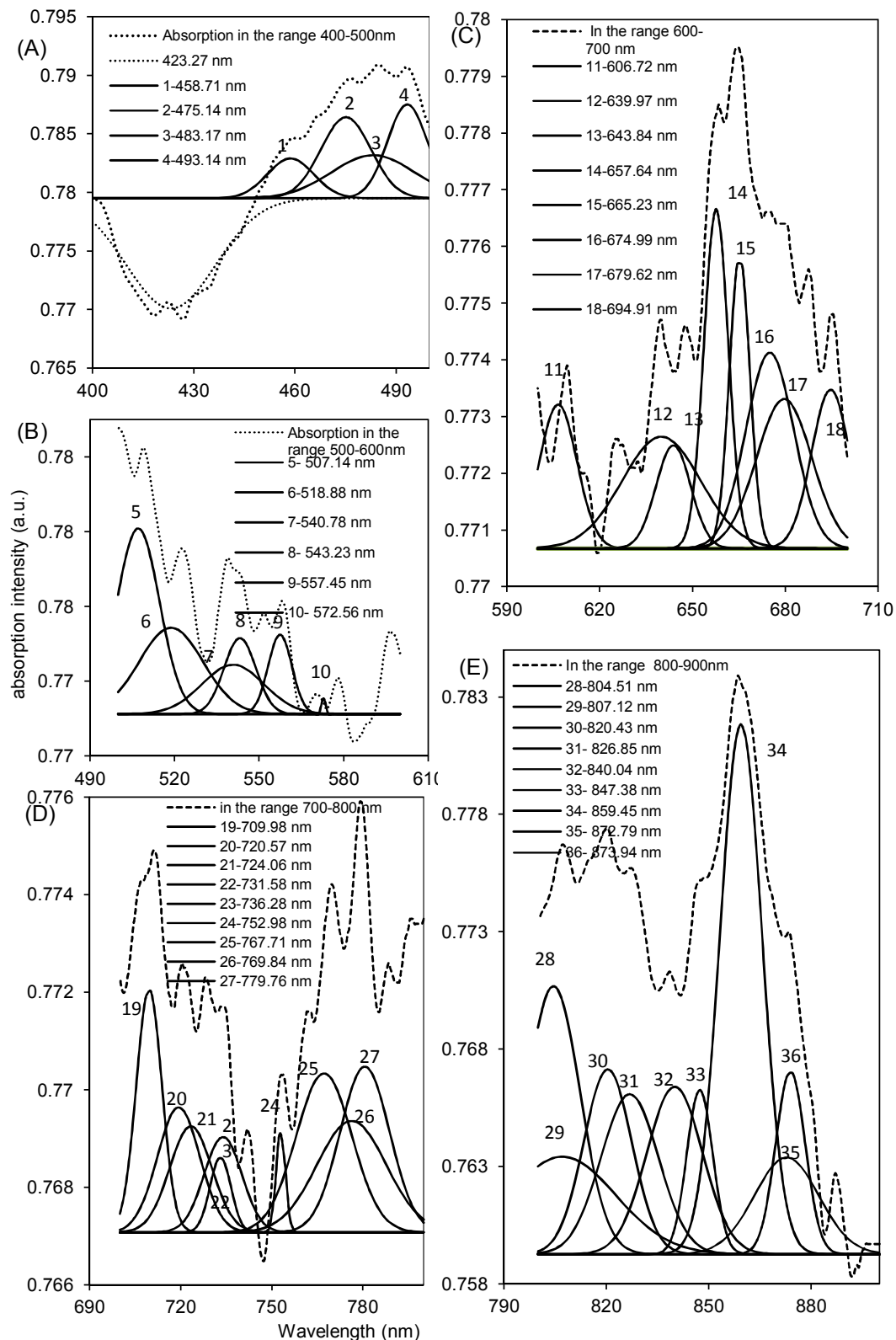


Figure 3: The absorption spectra of the red rain cells in the wavelength intervals of 100 nm. The deconvoluted Gaussian peaks are shown in solid lines. (A) in the range 400 - 500 nm, (B) in the range 500 - 600 nm, (C) in the range 600 - 700 nm, (D) 700 - 800 nm, (E) 800 - 900 nm. The deconvoluted spectra is showing large numbers of peaks. 36 peaks are observed which are labeled as 1 to 36 and given in the Table 1 along with the reported DIBs. Dotted lines represent the original spectrum.

2.3 Absorption Spectra of the Red Pigment Extracted from the Red Rain Cells

The red pigment of the red rain cells was extracted from the cells by immersing in the solvent DMSO at 90° C for a period of 16 hours. The UV-Visible and near IR absorption spectra of the extracted red pigment were recorded. They clearly show broad and finer features. There is a distinct peak at 334 nm, a broad peak centered at 440 nm and a shoulder peak at 558 nm as shown in Fig. 4. The spectrum also shows several weak absorption peaks as shown in Fig. 5 (a), Fig. 5(b) and Fig. 6 for the wavelength regions 600 - 700 nm, 700 - 800 nm and 800 - 900 nm respectively. These spectra registered 63 weak absorption peaks in the wavelength region 600 - 900 nm and are listed in Table 2 along with the reported DIBs. The spectrum does have features close to 4430 Å which is closest to the strongest DIBs in the ISM. The peak near 216.5 nm in the red cells as a whole is absent in the extracted pigment whereas a high intensity peak at 334 nm was observed.

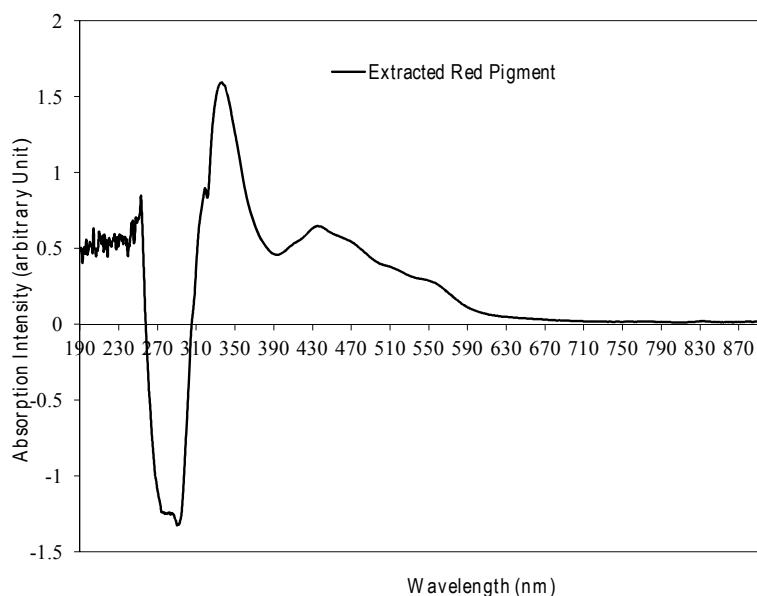


Figure 4: Broad absorption spectra of the red pigment extracted using DMSO from the red rain cells.

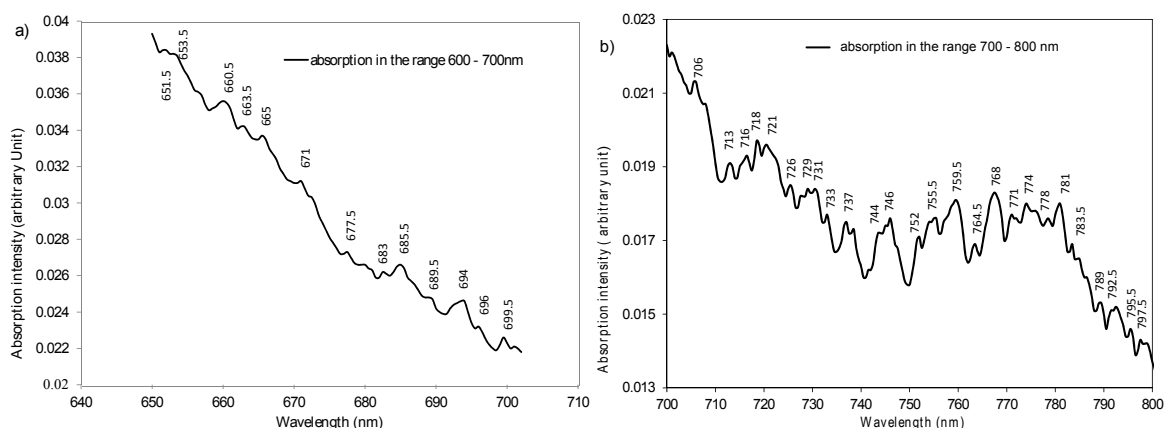


Figure 5: a) Absorption spectra of the extracted red pigment in the wavelength region 600 - 700 nm which registered 13 peaks b) Absorption spectra of the extracted red pigment in the wavelength region 700 - 800 nm which registered 26 peaks. These are listed and compared with DIBs in Table 2.

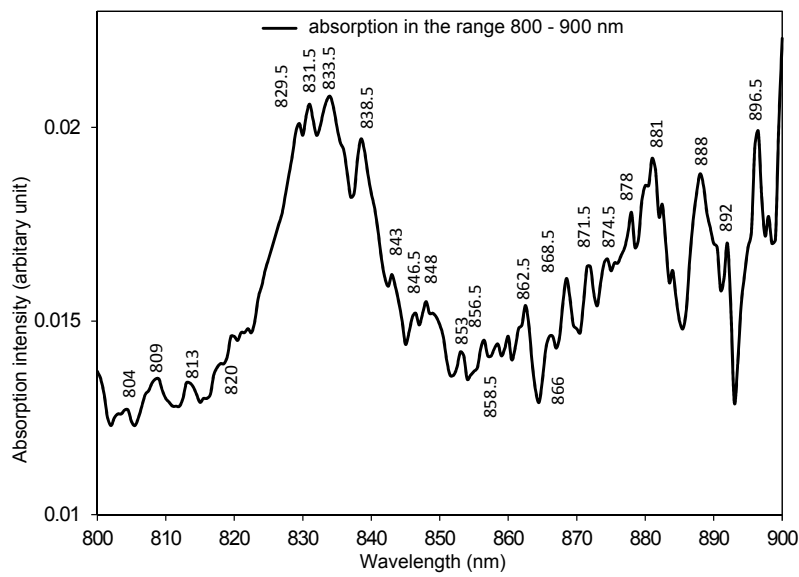


Figure 6: Absorption spectra of the extracted red pigment in the wavelength region 800-900 nm which registered 24 peaks. These peaks are listed and compared with DIBs in Table 2.

Table 1: Observed Absorption peaks of red rain cells compared with reported DIBs in ISM

Peak No.	Observed Peaks nm	FWHM nm	Reported DIBs \AA	Deviation nm	Peak No.	Observed peaks nm	FWHM nm	Reported DIBs \AA	Deviation nm
1.	458.71	13.737	4593.93	-0.68	19.	709.98	8.1545	7099.48	+0.03
2.	475.14	14.834	4762.57	-1.12	20.	720.57	12.510	7223.13	-1.74
3.	483.17	24.540	4825.94	+0.58	21.	724.06	13.431	7236.36	+0.42
4.	493.34	11.877	4951.05	-1.77	22.	731.58	5.2548	7321.08	-0.53
5.	507.14	15.179	5061.56	+0.98	23.	736.28	10.680	7360.45	+0.24
6.	518.82	22.671	5176.00	+1.22	24.	752.98	3.6058	7558.5	-2.87
7.	540.78	21.965	5404.52	+0.33	25.	767.71	17.469	7686.46	-0.94
8.	543.23	11.283	5419.05	+1.33	26.	769.84	14.102	7695.92	+0.25
9.	557.45	8.4210	5569.08	+0.54	27.	779.76	5.4460	7782.25	+1.53
10.	572.56	0.7748	5719.68	+0.59	28.	804.51	15.553	8038.48	+0.66
11.	606.72	15.357	6068.45	-0.13	29.	807.12	31.269	8040.08	+3.11
12.	639.97	25.355	6400.37	-0.07	30.	820.43	14.128		
13.	643.84	11.194	6439.42	+0.10	31.	826.85	16.794	8283.45	-1.5
14.	657.64	7.8575	6591.4	-1.5	32.	840.04	16.323		
15.	665.23	6.5904	6645.95	+0.63	33.	847.38	7.6525		
16.	674.99	15.499	6740.96	+0.89	34.	859.45	12.289	8621.11	-2.66
17.	679.62	17.901	6795.18	+0.1	35.	872.79	18.900		
18.	694.61	12.292	6944.53	+0.16	36.	873.94	8.6165		

Table 2: Observed absorption peaks of extracted pigment of the red rain cells compared with reported DIBs in ISM

No.	Observed peaks <i>nm</i>	Reported DIBs Å	Deviation <i>nm</i>	No.	Observed peaks <i>nm</i>	Reported DIBs Å	Deviation <i>nm</i>
1	334	3340.00	0.00	36	764.5	7651.37	-0.637
2	440	4430.00	-3	37	768	7686.46	-0.646
3	463	4666.65	-3.665	38	771	7709.67	+0.033
4	509	5110.89	-2.089	39	774	7748.18	-0.818
5	558	5569.08	+1.092	40	778	7782.25	-0.225
6	615	6151.15	-0.115	41	781		
7	618	6185.89	-0.589	42	783.5	7832.72	+0.228
8	651.5	6520.70	-0.57	43	789	7904.92	-1.492
9	653.5	6536.44	-0.144	44	792.5	7927.80	-0.28
10	660.5	6613.72	-0.872	45	795.5	7935.33	+1.967
11	663.5	6632.93	+0.207	46	797.5	7987.89	-1.289
12	665	6660.64	-1.064	47	804	8038.48	+0.152
13	671	6709.24	+0.076	48	809		
14	677.5	6770.05	+0.495	49	813		
15	683	6827.28	+0.272	50	820		
16	685.5	6852.90	+0.21	51	829.5	8283.45	+1.155
17	689.5	6886.92	+0.808	52	831.5		
18	694	6944.00	-0.400	53	833.5		
19	696	6978.54	-1.854	54	838.5		
20	699.5	6998.71	-0.371	55	843		
21	706	7060.81	-0.081	56	846.5		
22	713	7136.09	-0.609	57	848		
23	716	7161.21	-0.121	58	853		
24	718	7179.95	+0.005	59	856.5		
25	721	7223.13	-1.313	60	858.5	8530.79	+5.421
26	726	7264.98	-0.498	61	862.5	8621.23	+0.377
27	729	7287.62	+0.238	62	866	8648.28	+1.172
28	731	7321.08	-1.108	63	868.5		
29	733	7330.17	-0.017	64	871.5		
30	737	7369.29	+0.071	65	874.5		
31	744	7432.07	+0.793	66	878		
32	746			67	881		
33	752			68	888		
34	755.5	7558.50	-0.35	69	892		
35	759.5	7585.63	+0.937	70	896.5		

3 Concluding Remarks

Our investigation of the optical properties of the red rain cells showed a significant correlation with well-known interstellar extinction bump at 217.5 nm. Furthermore, the red rain cells exhibit many correspondences with the DIB's in the wavelength range 400 - 900 nm. In particular, the pigment extracted from the red cells showed a broad absorption peak centered on 440 nm and a high intensity peak at 334 nm. The density of absorption peaks was higher in the wavelength region 550 - 700 nm, similar to the situation for DIBs of the ISM. In conclusion we note that the interstellar absorption feature at 217.5 nm and the DIBs of the ISM are plausibly attributed to the presence of the red cells in the ISM. The red cells have unusual autofluorescence and a broad emission peak in the wavelength range 520 - 720 nm which can be correlated with ERE of the ISM and planetary nebulae. It has been reported elsewhere that the IR spectrum of the red rain cells of Kerala showed a correlation with several unidentified IR emission bands of protoplanetary nebulae [28].

The present identification of a correlation between the optical absorption features of red rain cells and its extracted pigment and the observed optical absorption features of interstellar medium is, in our view, highly significant. In conclusion we note that these results support the view that the red rain cells of both Kerala (2001) and Sri Lanka (2012) may have an extraterrestrial origin with an ubiquitous presence throughout the universe.

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