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Organic Molecules of Cometary Substance

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Abstract. Unidentified emissions are observed in spectra of most comets. These separate lines and bands were not possible to be identified earlier by standard methods. A great number of narrow lines of unknown nature were tabulated [11]. For solving the problem of unidentified cometary emissions, had developed the theoretical model of frozen hydrocarbon particles of icy halos of comets and described the mechanism of FHPs photoluminescence [6]. The comparison of laboratory and observed data showed that hundreds of cometary emissions not identified earlier are the photoluminescence of frozen hydrocarbon particles. In [6] particularly suggested that the mixture of frozen polycyclic aromatic hydrocarbons and alkanes can be among the ices of cometary nuclei. These mixtures are the solid solutions of substance – solvent type; here the substance means polycyclic aromatic hydrocarbon (PAH), and the solvent –acyclic hydrocarbons. The optical properties of the solution are determined by the properties of a solvent, by the conditions of crystallization of the solution, by the existence of luminescent component, by the character of interaction between the components of the solution and by the content of additional impurities in the solution. The surface layers of icy cometary nucleus are the sources of frozen hydrocarbon particles of different sizes ejected and carried to the circumnuclear area as the comet approaches the Sun. The size of individual FHP can vary from micron to millimeter. FHP can has the characteristic color inherent in frozen mixture of PAH and acyclic hydrocarbons. Simonia assumed that the solar ultraviolet radiation excites the photoluminescence of icy particles of halo. Low albedo of particles that consist of the mentioned mixtures, and the high quantum yield of photoluminescence of PAHs make it possible to register the corresponding luminescent emissions. The quantum yield of photoluminescence of FHPs can really be rather high. In favor of this assumption speaks the results of laboratory investigations. For the case of small grains containing the frozen organic mixture obtained the quantum yield of photoluminescence in the range of 90-100% [8]. UV photons of solar origin cause the photoluminescence of cometary FHPs in the range of 3800-7000 Å. We presented in this chapter results of studies of several comets.

Keywords: Solar System, comets, organic ice, frozen hydrocarbon particles, polycyclic aromatic hydrocarbons, luminescence.
PACS: 95.30.Ft, 95.30.Ky, 96.30.Cw, 96.55+z

INTRODUCTION

Resonance-fluorescent emissions of cold rarified comet atmospheres mark basic gas components forming these atmospheres. Emission lines of molecules and ions, such as C2,C3,CH,CN,CO2,NH,OH, CHII,COII,OHII, and others are basic components of cometary spectra. Basing the contemporary views on composition of cometary atmospheres on identification of emissions of resonance-fluorescence nature, it is concluded that the molecules of comas represent daughter formations. Solar short-wavelength electromagnetic radiation and fluxes of electrons and protons of the solar wind prevent hit of parent molecules into comas and tails, providing photodissociation and photoionization of these molecules. Spectrum of any comet rich in emission lines witnesses only daughter molecules and cometary atmosphere ions. This fact is well-known. However, there exists different component of cometary spectra, representing series of narrow emission lines not subject to standard methods of identification, including the method of comparison with the laboratory sources of radiation. Multiple narrow lines of unidentified nature are found in the spectra of majority of comets. Along with narrow lines we come across some relatively wide bands not subject to standard identification as well. Such lines, on common agreement, are named unidentified lines. Interest in unidentified

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cometary emissions is caused, firstly, by unknown nature of these lines and, secondly, by impossibility of applying standard methods of identification to them. Origin of these lines has more than once become the object of investigation. Main conclusion of these studies came to supposition on ionic nature of some emission lines of such type[1]. Majority of unidentified emission lines remained in the status of emissions of unknown nature. If relatively wide bands of unidentified nature observed in the spectra of ionic tails of comets can be linked with the corresponding ion, then multiple quite narrow unidentified lines observed in the spectra of comas demand thorough identification and discussion of other mechanisms of their excitation.

LUMINESCENCE OF COMETARY ICE AND DUST

Icy and mineral particles of cometary halo approaching the sun may exhibit luminescence under the influence of the solar X-ray, UV radiation, and the fluxes of high-energy electrons and protons. Solid cometary matter, processing the absorbing ultra-violet radiation of the sun, will emit luminescent photons of smaller energies. Registration of cometary solid matter luminescence suggests an opportunity to establish chemical-mineralogical composition and some physical parameters of this matter. Cometary spectra, along with emission lines, are also characterized with faint continuum of solar origin. Icy and dust particles of cometary halos, scattering optical solar radiation condition the appearance of such a continuum. Our attention will be concentrated at the complex of unidentified emission lines of cometary spectra.

Polycyclic aromatic hydrocarbons, wide-spread in the universe, contained in the substance of comets [2], [3],[4]. It was proposed in the works [5], [6] that the cometary nuclei can contain frozen mixtures of polycyclic aromatic hydrocarbons and alkanes, for example, Phenanthrene + n-hexane or Coronene + n-heptane. As the comet approaches the sun, during intensification of the processes of ice sublimation and mechanical destruction of cometary nucleus surface layers, there takes place ejection of fine-grained icy particles into cometary atmosphere. This process, in greater extent, causes formation of icy cometary halos of characteristic size comets contain fine-grained icy particles consisting of frozen mixture of polycyclic aromatic hydrocarbons and alkanes. Icy particles of such kind can contain additional impurities as the component of solid solution or mechanical inclusions, for example, inclusions in the form of carbonaceous particles of submicron sizes. Fine-grained icy particles, the matter of which consists of frozen mixture of hydrocarbons (FHP), are contained in the icy halo of comets, characterized by corresponding sizes and form, being micro-fragments of polycrystalline solutions of hydrocarbons—constituent of icy cometary nuclei.

Solar ultraviolet radiation excites photoluminescence of FHP of icy cometary halo. UV photons, absorbed by icy particles substance, re-emit by it in the form of photons of smaller energies within the visible range of the spectrum. Fluxes of electrons and protons of high energies can also excite luminescence of FHP—the process of cathodoluminescence of icy particles. Spectral composition of FHP luminescence depends on: a) chemical composition of concrete icy particle; b) PAH concentration in the particle substance; c) particle substance temperature; d) presence or absence of additional luminescent impurities in the particle substance; e) phase of solar activity. Complex organic mixtures in conditions of room temperature are characterized by the luminescence spectra in the form of wide featureless bands. Laboratory experiments revealed that: if

PAH molecules are dissolved in alkanes at 77 K or low, aromatic molecules will isolated each from other and fixed in the solvent. Such matrix is characterized by luminescence spectra in the form of series of narrow lines—quasi-linear spectra [7]. In cometary ices frozen mixtures of PAHs and alkanes may emit narrow luminescence lines on the specific heliocentric distances were temperature of ices is around 77 K or low. The laboratory data point to the fact that analogs of FHP of icy cometary halo can potentially possess: 1. Photoluminescence spectra in the form of wide featureless bands; 2. Photoluminescence spectra containing series of very narrow lines. Existence of Schpolski matrix in cometary ices is highly possible due to low temperature of cometary bodies and numerous organic compounds in cometary substance.

Detectability of photoluminescence emissions of cometary FHP is an important factor. In [8] proposed that quantum yield of luminescence of small grains containing organic mixtures variate within 90–100%. These laboratory data point to bright luminescence of organic mixture excited by UV radiation. We calculated for conditions of real cometary halo, the ratio of flux of luminescence to the flux of scattered solar radiation F_{lum}/F_{scat}. The following conditions were taken: FHP of millimeter size; chemical composition of particles Phenanthrene + n-hexane; albedo of particles $A = 0.1$; FHP luminescence yield $q = 50$ per cent. We calculated mentioned ratio for spectrum ranges with different width and wavelength using values of solar UV and optical fluxes on the distance 1 a.u. obtained from different sources, including [9]. Calculations suggested that for considered FHP of icy cometary halo the ratio F_{lum}/F_{scat} varies within 1.2–4.3. Calculations suggested also that solar UV radiation in range 3000–3800 Å effectively excites cometary FHP luminescence in range 4000–7000 Å. This means that in many cases luminescence signal of FHP lies over scattered solar continuum. This signal represents faint, but quite fixed emission. Such faint unidentified emissions are widely presented in spectra of many comets.

We compared the laboratory photoluminescence spectra of FHP substance analogs with the observed cometary spectrum containing a set of unidentified emission lines. We used an atlas of quasi-line photoluminescence spectra of aromatic molecules [10] as the laboratory data and atlas of high resolution spectrum for comet 122P/de Vico [11] as the observational data. The results obtained are summarized in the table1.

TABLE 1. Photoluminescent emissions of the cometary spectrum 122P/de Vico

PAHs	Solvents	Laboratory emissions	Cometary emissions
1. Pyrene $C_{16}H_{10}$	n-hexane	3929 5894 6027 6036 6346 6413 6509	3929.28 5893.85 6026.66 6036.42 6346.78 6413.07 6508.71
2. 1,2-3,4-Dibenzanthracene $C_{22}H_{14}$	n-octane n-hexane	3862 3936 3949 4069 4091	3862.07 3936.23 3949.15 4069.03 4090.99

		3934 3955 3981 4055 4067	3934.90 3955.13 3981.64 4054.64 4067.35
3. Pycene $C_{22}H_{14}$	n-hexane	3863 3871 3989 3999 4186	3863.16 3871.63 3989.37 3999.89 4186.75
4. 1,2-Benzopyrene $C_{20}H_{12}$	n-hexane	3862 3960 3959 4074 4088 4103 4195 4212 4310 4324 5366 5349 5479 5718 5754 6016 6351	3862.07 3960.05 3959.12 4073.30 4087.97 4102.98 4194.46 4212.69 4310.10 4324.09 5366.02 5349.22 5479.25 5718.11 5753.51 6015.19 6351.65
5. Anthracene $C_{14}H_{10}$	n-hexane	3950 3963 3985 4011 4023 4075	3950.02 3963.11 3985.44 4011.44 4023.07 4075.98
	n-heptane	4248 4264 4292 4490 4519 3867 3967 3987 4002 4025 4064 4094 4295 4541 4573	4248.06 4263.07 4291.73 4489.90 4519.09 3867.16 3967.51 3987.26 4001.97 4024.93 4064.46 4093.94 4294.88 4540.82 4572.97
6. Tetraphene $C_{18}H_{12}$	n-hexane	3884 3886 3934	3884.72 3886.61 3934.90

		3956	3956.48
		3961	3960.05
		3963	3963.11
		3999	3999.89
		4034	4034.01
		4044	4044.38
		4047	4046.74
		4063	4062.87
		4085	4084.85
		4096	4095.93
		6415	6415.14
		6439	6438.24
		6510	6509.91
	n-octane	6638	6638.21
		3891	3891.48
		3909	3908.67
		3912	3912.14
		3925	3924.82
		3929	3929.28
		4005	4005.94
		4038	4037.93
		4041	4041.94
		4046	4046.36
		4069	4069.03
		4070	4069.97
		4095	4094.78
		4098	4098.31
		5910	5909.17
		5935	5935.42
7. 1,2-5,6-Dibenzanthracene $C_{22}H_{14}$	n-hexane	3936	3936.23
		3950	3950.02
		3953	3953.19
		4044	4044.38
		4045	4045.35
		4148	4148.93
		4195	4194.46
		5542	5542.40
		5942	5942.25
		6013	6012.37
		6096	6096.48
		6135	6135.00
8. 1,2-4,5 Dibenzpyrene $C_{24}H_{14}$	n-hexane	3936	3936.23
		3950	3950.02
		3953	3953.19
		4002	4001.97
		4062	4062.86
		4186	4186.75
		4621	4620.97
		4657	4656.89

		4696 4809 4888	4695.85 4809.87 4888.45
9. Diphenyl $C_{12}H_{10}$	n-hexane	4371 4570	4371.16 4570.12
10. Fluorene $C_{13}H_{10}$	n-hexane	4239 4525 4552	4238.71 4525.13 4552.25
11. Diphenyloxide $C_{12}H_8O$	n-hexane n-heptane	4093 4358 4539 4069 4299 4359 4507 4528	4092.85 4358.36 4539.54 4069.03 4299.70 4359.04 4507.03 4527.85
12. Dibenzothiophene $C_{12}H_8S$	n-hexane n-heptane	4152 4212 4304 4355 4578 4094 4256 4491 4549	4151.30 4212.69 4304.91 4354.46 4577.93 4093.94 4256.60 4491.45 4548.99

13. Triphenylene $C_{18}H_{12}$	n-hexane	4373 4487 4490 4539 4550 4523 4610 4615 4617 4646 4706 4849 4921 4951	4372.63 4487.93 4489.90 4539.54 4549.99 4522.77 4609.93 4615.39 4617.14 4646.15 4706.03 4849.20 4920.31 4950.46
14. Phenanthrene $C_{14}H_{10}$	n-hexane	4591 4602 4957 4991 5060 5313 5327	4591.28 4602.17 4957.43 4991.97 5060.23 5313.29 5327.89

		5400	5400.20
15. Chrysene $C_{18}H_{12}$	n-hexane	4000 4983 5028 5058 5318 5352 5422 5510	4000.09 4982.63 5028.42 5057.71 5318.08 5352.12 5422.38 5509.39
16. 9-10-Dimethyltetraphene $C_{20}H_{14}$	n-hexane	4033 4055 4072 4080 4194 4248 4258 4303	4032.47 4054.64 4072.13 4079.43 4194.05 4248.06 4257.46 4303.34
17. 3,4-Benzopyrene $C_{20}H_{12}$	n-hexane	4020 4024 4027 4075 4079 4263 4300 4304	4019.85 4023.91 4027.50 4075.98 4079.43 4263.07 4300.90 4304.34
		4328 4507 4533 4584	4328.25 4507.43 4532.77 4584.65
	n-octane	4030 4085 4242 4269 4275 4305 4330 4517 4538 4590	4029.19 4085.89 4242.50 4269.88 4274.84 4304.91 4329.69 4516.89 4538.36 4590.13
18. 1,12 – Benzperylene $C_{22}H_{12}$	n-hexane	4060 4258 4294 4303 4308 4435 6151	4059.87 4257.46 4294.88 4303.34 4308.05 4435.93 6150.94

		6162 6262 6312	6162.28 6261.12 6312.90
19. Fluoranthene $C_{16}H_{10}$	n-hexane	4058 4136 4154 4254 4276 4337 4365 6156	4057.96 4135.38 4154.86 4254.78 4275.39 4336.95 4365.20 6155.75
20. Pentaphene $C_{22}H_{14}$	n-hexane	4234 4306 4317 4320 4322 4472 4485 4499 4533 4526 4806 4842	4234.76 4306.43 4316.96 4320.02 4322.79 4472.31 4485.29 4499.22 4533.36 4525.99 4806.55 4842.12
21. Coronene $C_{24}H_{12}$	n-hexane	4330 4434 4451	4329.69 4433.11 4451.59
		4543 4536 4550 5159 5260 5510 5615 5630 5930	4543.00 4536.33 4549.99 5159.89 5260.31 5509.39 5615.23 5629.74 5929.59
22. 3,4-9,10-Dibenzpyrene $C_{24}H_{14}$	n-hexane	4303 4308 4357 4466 4574 4580 4586 4632 4890	4303.34 4308.05 4356.23 4466.05 4574.09 4580.24 4586.10 4632.93 4890.01
23. Anthanthrene $C_{22}H_{12}$	n-hexane	4328 4333	4328.25 4333.17

		4555	4555.21
		4561	4560.69
		4558	4558.04
		4575	4575.11
		4600	4600.80
		4658	4658.89
		4571	4570.89
		4910	4909.70
		4971	4971.91
24. Perylene $C_{20}H_{12}$	n-hexane	4433	4433.11
		4454	4454.10
		4514	4514.30
		4526	4525.99
		4566	4566.01
		4601	4600.99
		4728	4728.93
		4745	4744.63
		4791	4791.59
		4809	4809.87
		4827	4826.95
		4874	4874.12
25. 3,4-8,9-Dibenzpyrene $C_{24}H_{14}$	n-hexane	4481	4481.10
		4485	4485.29
		4534	4533.36
		4542	4542.79
		4589	4589.01
		4596	4595.89
		4617	4617.19
		4744	4744.04
		4750	4750.96
		4751	4750.96
		4784	4784.10
		4788	4788.17
		4821	4821.61
		4830	4830.73
		4835	4835.04
		4840	4840.06
26. 1,2-Benztetracene $C_{22}H_{14}$	n-hexane	4518	4518.14
		4530	4529.97
		4575	4575.11
		4590	4590.13
		4777	4777.06
		4811	4811.37
		4834	4833.84
		4870	4869.95
		4892	4892.50

27. 2,3-Orthophenylenepyrene $C_{22}H_{12}$	n-hexane	4650	4649.92
		4810	4809.87
		4915	4915.25
	n-octane	5025	5025.12
		4625	4625.05
		4632	4632.93
		4672	4672.56
		4705	4705.59
		4715	4715.53
		4763	4763.03
		5005	5005.82
28. Tetracene $C_{18}H_{12}$	n-hexane	4751	4750.96
		5087	5086.61
	n-nonane	5238	5237.57
		4719	4719.17
		4794	4794.01
		4866	4866.26
		5135	5135.96
		5176	5176.26
		5197	5197.21
		5219	5218.65

It gives the PAH names (column1), the solvent names (column 2), the wavelength of the photoluminescent emission lines of the corresponding polycrystalline solutions (column 3), and the wavelength of unidentified cometary emissions from the spectrum of comet de Vico (column 4). We performed comparative analysis with an accuracy of ±1Å. Having performed a comparative analysis of the observational and laboratory data, the results of which are summarized in table 1 we conclude that at least 28 aromatic hydrocarbons that constitute a polycrystalline solution with a number of alkanes may be contained in the FHPs of the ice halo of comet de Vico as the main mixture. FHPs will also contain impurities in small amount. In fact the ice halo of comet de Vico may be a complex of FHPs of various chemical compositions. A cloud of variously sized FHPs with different chemical compositions exposed to ultraviolet solar radiation will be a source of photoluminescent emission lines within a wide wavelength range, 3800-7000 Å.

Aromatic hydrocarbons can exist in comets in both condensed and gas phases. The described FHPs are the carriers of a number of previously unidentified photoluminescent emission lines.

The work [12] contains detailed catalogue of emission lines of the spectrum of comet 153P/Ikeya-Zhang. In this catalogue 8468 emission lines are tabled. From this amount 1862 emission lines had the status of unidentified. We conducted comparative analysis of the spectral positions of unidentified emission lines in the spectrum of comet 153P/Ikeya–Zhang [13] with the spectral positions of photoluminescence emission lines of chemical analogs of cometary FHPs in the form of polycrystalline solutions PAH+alkanes. As the laboratory data we used the atlas of quasi-linear spectra of luminescence of aromatic molecules and other materials [10], [14], [15]. In this case, the criteria for selection were coincidence of spectral positions of corresponding emission lines within ±1 Å and in similarity of their profiles.

Table 2 shows the results of our comparative analysis. In column 1 are given wavelengths of cometary emission lines having the status of unidentified in the catalogue [12]. Column 2 presents the wavelengths of luminescence emission lines of polycrystalline mixtures (PAH+alkanes) selected from [10], [14], [15]. Column 3 presents names of relevant polycyclic aromatic hydrocarbons and column 4 - names of relevant aliphatic hydrocarbons—solvents. In result of comparative analysis we have managed to identify 21 molecules of polycyclic aromatic hydrocarbons being in the content of FHPs matter of icy halo of comet 153P/Ikeya-Zhang. To these molecules are attributed Phenanthrene, Pyrene, Chrysene, Coronene, etc. Comparative analysis suggested, in particular, that 72 lines of 153P/Ikeya-Zhang spectrum represent photoluminescence emission lines of frozen mixtures PAH+alkanes, being cometary FHP matter. Photoluminescence emission lines, identified by us, made up 3.8 per cent of the total number of earlier unidentified emission lines of the mentioned comet. The rest 96.2 per cent of emission lines still remained in the status of unidentified. These emission lines demand further investigations considering high probability of their ionic nature.

Thus, icy halo of 153P/Ikeya-Zhang comet contains the complex of frozen hydrocarbon particles icy grains of different forms and sizes luminesce in visual range of the spectrum. There takes place photoluminescence of FHP in form of phosphorescence and fluorescence with after glowing period $\tau > 0$ and $\tau = 0$, respectively. Luminescence of cometary FHP can be also caused by bombarding by fluxes of fast electrons of solar origin, more because the solid bodies photoluminescence and cathodoluminescence are too much alike, differing only in the means of leading the exciting energy to the corresponding body.

We have revealed in the spectrum of 153P/Ikeya-Zgang comet photoluminescence emission lines on the wavelengths of 4602.14 Å and 6134.99Å. Photoluminescence emissions with almost same wavelengths were revealed by us in the spectrum of comet 122P/de Vico (4602.17, 6135 ÅÅ). The above-said suggests in favor of similarity of chemical composition of FHP icy halo of the mentioned comets. Thus, frozen hydrocarbon particles of different cometary icy halo, as in general, ices of their nuclei can be too close, similar by chemical composition (under chemical composition we understand composition of mixture PAH+alkanes).

TABLE 2. Photoluminescent emissions of the cometary spectrum 153P/Ikeya-Zhang

Observed lines	Laboratory data	PAHs	Solvents
4600.98	4601	Perylene	n-hexane
4602.14	4602	Phenantrene	n-hexane
4602.37	4603	3-Methylperylene	n-octane
4610.09	4610	Perylene	n-hexane
4614.19	4614	3,4-8,9 Dibenzpyrene	n-hexane
4615.39	4615	3-Methylperylene	n-octene
4617.13	4617	Triphenylene	n-hexane
4623.31	4623.3	Perylene	n-hexane
4646.13	4646	Triphenylene	n-hexane
4649.47	4649	Diphenyleneoxid	n-hexane
4649.91	4650	perylene	n-hexane
4706.04	4706	Triphenylene	n-hexane

4719.17	4719	Tetracene	n-hexane
4742.97	4743	1,2-3,4 Dibenzpyrene	n-hexane
4763.01	4763	2,3 Ortophenylenepyrene	n-octane
4769.04	4769	Perylene	n-hexane
4769.57	4770	Benzo[j]Fluorantene	n-hexane
4774.25	4774	3-Methylperylene	n-octane
4794.24	4794	Tetracene	n-hexane
4811.36	4811.65	Benzo[j]Fluorantene	n-hexane
4826.91	4826.6	Benzo[j]Fluorantene	n-octane
4827.40	4827	Perylene	n-hexane
4840.49	4840	Benzo[j]Fluorantene	n-hexane
4842.12	4842	Pentafene	n-hexane
4849.20	4849	Triphenylene	n-hexane
4858.46	4858	3-Methylperylene	n-octane
4866.80	4866	3-Methylperylene	n-octane
4874.10	4874	Perylene	n-hexane
4874.92	4874.95	Benzo[j]Fluorantene	n-hexane
4890.25	4890	3,4-9,10 Dibenzpyrene	n-hexane
4893.46	4893.3	Benzo[j]Fluorantene	n-octane
4897.38	4897	3,4-9,10 Dibenzpyrene	n-hexane
4915.23	4915	2,3 Ortophenylenepyrene	n-octane
4925.96	4925	3-Methylperylene	n-octane
4950.46	4950	Benzo[j]Fluoranthene	n-octane
4984.07	4984.3	Benzo[j]Fluoranthene	n-hexane
4985.09	4885	Naphtacene	n-nonane
5025.12	5025	2,3 Orthopenylenepyrene	n-hexane

5028.42	5028	Chrysene	n-hexane
5060.23	5060	Phenanthrene	n-hexane
5086.61	5087	Tetracene	n-hexane
5176.26	5176	Tetracene	n-nonane
5197.20	5197	Tetracene	n-nonane
5218.61	5219	Tetracene	n-hexane
5249.97	5250	9-Hexylphenanthrene	n-hexane
5260.34	5260	Coronene	n-hexane
5318.22	5318	Chrysene	n-hexane
5349.21	5349	1,2,Benzpyrene	n-hexane
5352.10	5352	Chrysene	n-hexane
5366.46	5366	1,2,Benzpyrene	n-hexane
5479.24	5479	1,2,Benzpyrene	n-hexane

5542.36	5542	1,2,-5,6 Dibenzantracene	n-hexane
5615.20	5615	Coronene	n-hexane
5629.74	5630	Coronene	n-hexane
5680.20	5680	9-Hexylphenanthrene	n-hexane
5870.04	5870	1,2 Benzpyrene	n-hexane
5894.21	5894	Pyrene	n-hexane
6026.65	6027	Pyrene	n-hexane
6036.40	6036	Pyrene	n-hexane
6096.48	6096	1,2-5,6 Dibenzantracene	n-hexane
6134.99	6135	1,2-5,6Dibenzantracene	n-hexane
6150.95	6151	1,12 Benzperylene	n-hexane
6276.23	6276	1,12 Benzperylene	n-hexane
6415.16	6415	Tetraphene	n-hexane
6460.05	6460	9-Hexylephenanthrene	n-hexane
6508.74	6509	Pyrene	n-hexane
6638.21	6638	Tetraphene	n-hexane
7029.93	7030	9-Hexylephenanthrene	n-hexane
7810.16	7810	9-Hexylephenanthrene	n-hexane

Figures 1 and 2, are showed relevant fragments of 153P/Ikeya-Zhang comet spectra and photoluminescence spectrum of laboratory analogs of cometary FHP matter in the form of frozen mixture of 3-Methylperylene with n-octane. Attention is attracted by resemblance of profiles of earlier unidentified cometary emission lines with the profiles of photoluminescence emission lines of frozen matter of the chemical composition mentioned above. Concentration of aromatic molecules in mixture within 10^{-3}–10^{-2} mol L^{-1} provides formation of luminescence quasi-lines and probably detectability of such luminescence in cometary spectra.

ASPECTS OF THE PROBLEM

We have revealed that from the total number of unidentified emissions of 122P/de Vico and 153P/Ikeya-Zhang comet spectra certain quantity of emissions have photoluminescence nature.

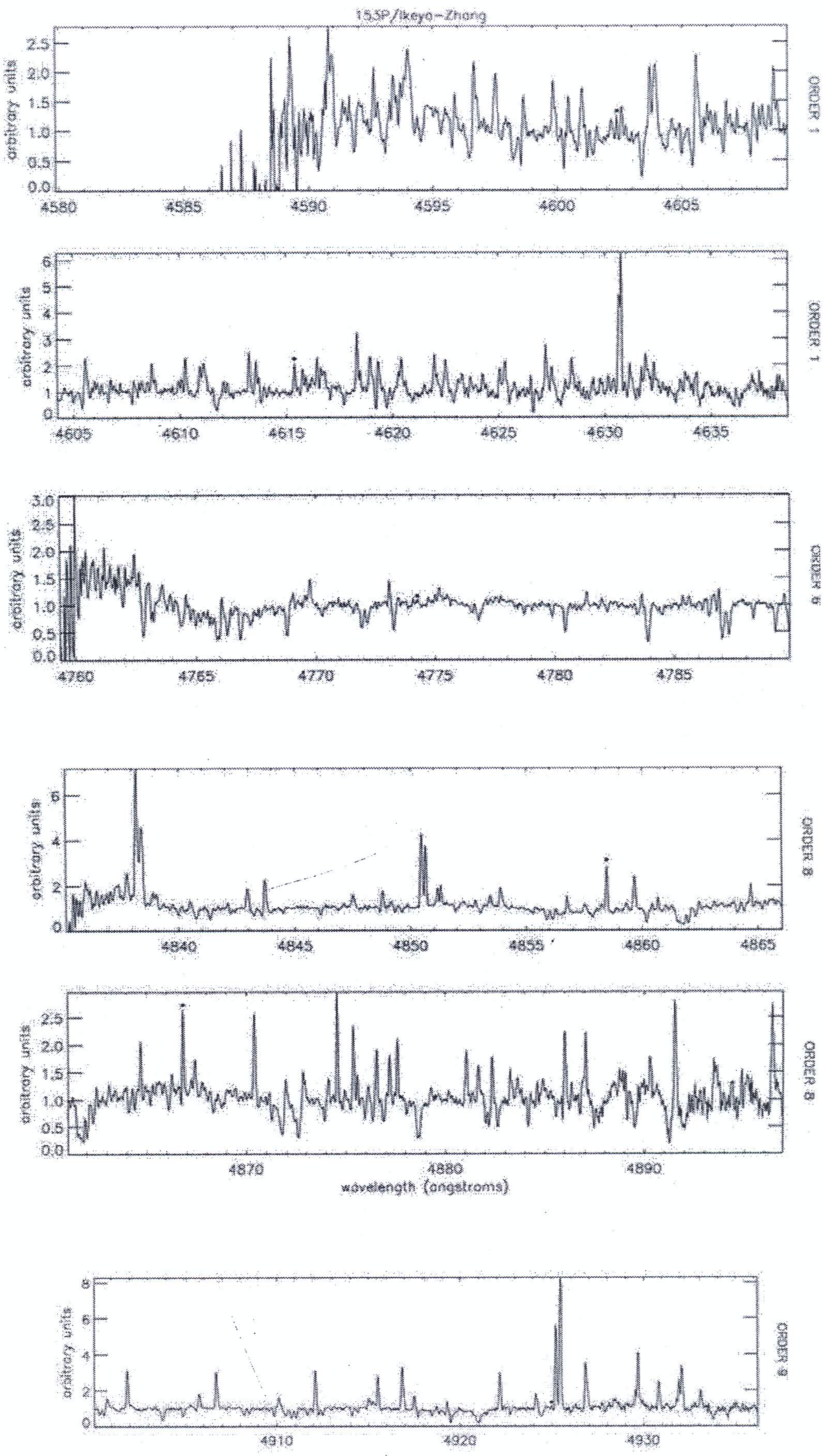

FIGURE 1. Fragments of 153P/Ikeya-Zhang comet spectrum [12.]We consider lines 4602.377; 4615.39; 4774.250; 4858.467; 4866.808; 4924.960Å as photoluminescence of cometary FHPs.

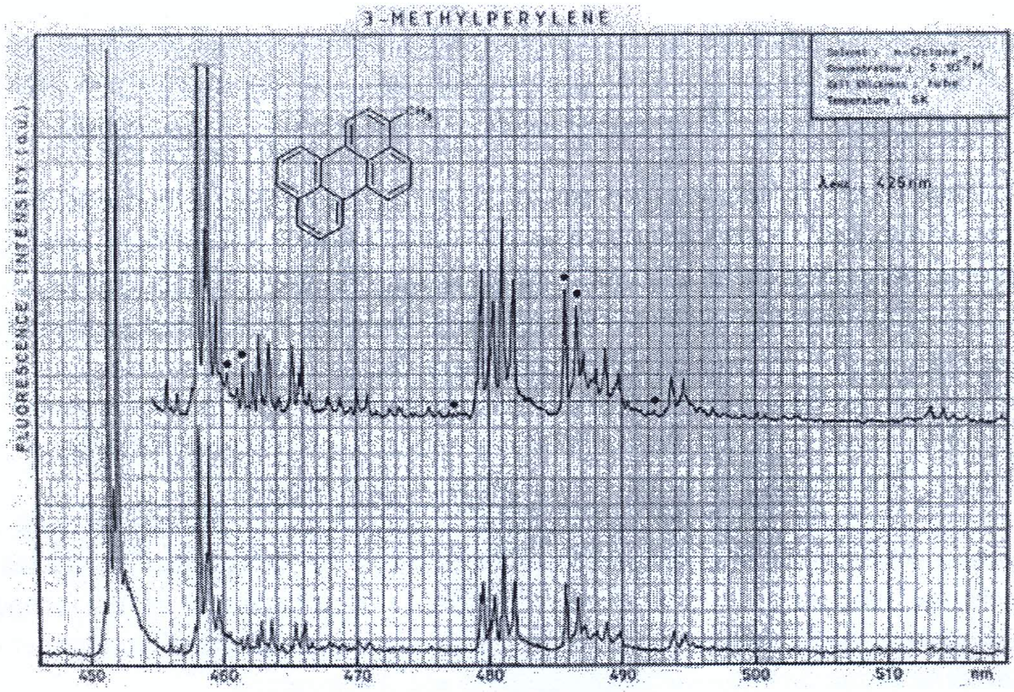

FIGURE 2. Fragments of photoluminescence spectra of frozen mixture 3-Methylperylene and n-octane [14]. Emission lines at 460.3; 461.5; 477.4; 485.8; 486.6; 492.5 nm coinsides in spectral positions and profiles with cometary emission lines.

Under influence of solar ultraviolet radiation polycyclic aromatic hydrocarbons and alkanes in the form of frozen mixture, constituting icy halo particles matter, may luminesce in the optical spectral range, being source of narrow lines series. Icy halos of these comet abounds in organic compounds in the form of frozen aromatic and aliphatic hydrocarbons. Study of cometary ices luminescence enables to determine their exact chemical composition and, in certain cases, the temperature. Presence of noticeable organic component in the cometary ices in the form of hydrocarbons mixtures witnesses that other icy bodies, including ice-covered bodies (satellites of giant planets), can luminesce under the influence of shortwavelength solar radiation and fluxes of solar wind charged particles. This means that detection of such luminescence and correct interpretation of the obtained data enable as minimum to determine chemical composition of these bodies. In laboratory environment spectral parameters of PAH+alkanes luminescence were obtained with the high accuracy [10], [14]. Many quasi-lines of luminescence spectra of mentioned solid mixtures are measured with accuracy less than ±1 Å. Using of such comparative lab data is suitable for identification of PAH+alkanes luminescence emissions in cometary spectra. We identified six luminescence emission lines of 3-Methylperylene solved in n-octane in spectra of 153P/Ikeya-Zhang comet (Fig. 1). Other luminescence emission lines of mentioned frozen mixture are not identified in optical spectra of this comet: 1) concentration of aromatic molecules in alkanes probably is different in laboratory samples and in cometary icy particles; 2) frozen hydrocarbon particles of cometary halos probably consist from complex mixture solid solution of several PAHs in alkanes. In laboratory were studied simple specific mixtures PAH in alkanes, while cometary icy matter as natural substance will consist from complex aromatic molecules solved in alkanes. Circumstances 1), 2), explain why we are unable to reveal in cometary spectra whole set of laboratory luminescence emission lines of specific frozen mixture. Luminescence spectra of simple PAH+alkane solid solutions will always differ from luminescence spectra of cosmic substance consisted from complex aromatic molecules solved in alkanes. Not only UV radiation of the Sun may excites luminescence of cometary FHPs. Visible solar radiation in range 4000–4300 Å may also excites luminescence of icy particles of cometary halos.

Surface of the icy cometary nuclei can also luminesce under the influence of solar shortwavelength radiation. This may happen only at great heliocentric distances under conditions of cometary halo absence. Instrumental registration of possible luminescence of cometary nuclei will be quite a difficult task, taking into consideration great geocentric distance of "naked" cometary nuclei.

The 122P/de Vico and 153P/Ikeya-Zhang comets spectra show several similar photoluminescence emission lines of FHPs (table 1-2). This means that, in different comets, FHPs of icy halos may have similar chemical composition.

The properties of FHP photoluminescence emission lines may change with different heliocentric distances. Widening of such lines might be determined by decreasing the heliocentric distance of the comet. An accurate determination of the properties of photoluminescence line requires spectroscopic observations of specific comets at different heliocentric distances using the same telescope and spectrograph.

CONCLUSION

We have described peculiarities of FHP photoluminescence of icy cometary halo. Comparative analysis has been conducted of spectral positions of unidentified emissions of the spectra of comets 122P/de Vico [11] and 153P/Ikeya-Zhang [12] given with luminescence emissions of PAHs in alkanes [10], [14,] and others. Luminescence of icy particles of the halos of comets can become a new channel of information on cometary substance. Detection and comprehensive study of the luminescence of organic components of icy particles of the cometary halos will be of great importance for the field of astrobiology.

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