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FROZEN HYDROCARBONS IN COMETS

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ABSTRACT

Recent investigations of the luminescence of frozen hydrocarbon particles of icy cometary halos have been carried out. The process of luminescence of organic icy particles in a short-wavelength solar radiation field is considered. A comparative analysis of observed and laboratory data leads to 72 luminescent emission lines in the spectrum of the comet 153P/Ikeya-Zhang. The concept of cometary relict matter is presented, and the creation of a database of unidentified cometary emission lines is proposed.

Key words: comets: general – comets: individual (153P/Ikeya-Zhang) – dense matter – radiation mechanisms: non-thermal

1. INTRODUCTION

Resonance–fluorescence emissions of cold cometary atmospheres are indications of the gas components that form these atmospheres. Emissions of molecules and ions, such as C2, C3, CH, CN, CO2, NH, OH, CH II, CO II, and others, are the main components of cometary spectra. Based on contemporary notions of the chemical composition of cometary atmospheres regarding the identification of molecular resonance–fluorescence emissions, we conclude that the molecules of cometary comas represent daughter formations. Solar short-wavelength electromagnetic radiation and fluxes of charged particles of the solar wind prevent penetration of parent molecules into comas and comet tails, providing photodissociation and photoionization of these molecules. The processes of molecule photodissociation and photoionization are continuous in near-nucleus space. Thus, it is well known that the spectrum of any comet rich in emission lines exhibits only daughter molecules and cometary atmosphere ions. However, different components of cometary spectra exist, representing a series of narrow emission lines not subject to standard methods of identification, including comparison with laboratory radiation sources. Multiple unidentified narrow lines are found in the spectra of the majority of comets. Along with these narrow lines, we come across some relatively wide bands not subject to standard identification. Such lines, by common agreement, are named unidentified lines. Many authors have presented data on such emission lines in tables and catalogs, publishing them alongside tables of identified emissions. Interest in unidentified cometary emission lines arises, first, due to their unknown nature and, second, due to the difficulty in applying standard methods of identification to them. The origin of these lines has frequently been the object of research. The main conclusions of these studies speculated on the ionic nature of some of these emission lines (Wyckoff et al. 1999; Kawakita & Watanabe 2002). However, the majority of unidentified emission lines remained unclassified. If relatively wide unidentified bands observed in the spectra of ionic tails of comets can be linked with a corresponding ion, then multiple narrow unidentified lines observed in the spectra of comas require thorough investigation and discussion of other excitation mechanisms.

In the works of Simonia (2004, 2007a, 2007b) a theoretical model of frozen hydrocarbon particles of icy halos of comets was presented and the mechanisms of frozen hydrocarbon particle (FHP) luminescence were discussed. It was proposed that under the influence of solar electromagnetic and corpuscular radiations, solid components of comet matter, including ice, icy particles, and silicate dust, may exhibit luminescence within the visible spectral range. Photoluminescence of solid cometary matter will be, in most cases, subject to Stokes' law, and the maximum of the photoluminescence spectrum will be shifted in the direction of the long wavelength in relation to the absorption spectrum maximum $\lambda_{\rm lum} > \lambda_{\rm abs}$. Simonia (2007b) explained the unidentified emissions observed in cometary spectra as FHP luminescence of icy cometary halos. The properties of icy cometary halos are still under consideration. For example, Fernandes & Jockers (1983) suggested that an icy cometary spherical halo may have a radius of approximately 500 km. Absorption features of water ice in the NIR spectrum of comet C/2002 T7 (Linear) were detected by the Subaru telescope (Kawakita et al. 2004a). The *J*, *H*, *K* bands of the spectrum of this comet showed 1.5 and 2.0 μm features of water ice in amorphous form. The absorption feature detected at 2.2 μm was attributed to other materials, including hydrate ices. Kawakita et al. (2004b) showed that comets may have icy halos at the heliocentric distance $r > 3$ AU. They noted that ice grain sizes in the cometary halo may vary within 0.1–10 μm. Generally speaking, different observational data models (Combi & Tenishev 2005) have confirmed the existence of cometary icy halos, though the physical properties of grains and their chemical compositions are little understood. Having studied the spectra of comets 122P/de Vico, 23P/Brorsen-Metcalf, and 109P/Swift-Tuttle, Simonia (2007b) proposed, in particular, that comets with up to 14% of unidentified emission lines represent photoluminescence FHP, and so 86% of unknown emissions remained unidentified. Icy and mineral particles of cometary halos approaching the Sun may exhibit luminescence under the influence of solar X-ray, and UV radiation, and the fluxes of high-energy electrons and protons. Solid cometary matter processing the absorbing UV radiation of the Sun will emit luminescent photons with lower energies $E_{\rm lum} < E_{\rm abs}$. The detection of cometary solid matter luminescence provides an opportunity to establish its chemical–mineralogical composition and some of its physical parameters. In fact, the 14% of cometary emission lines mentioned above, previously unidentified and now considered as FHP photoluminescence emissions, are indicators of the chemical composition of icy cometary halos.

Naturally, the luminescence of silicate and carbonaceous dust constituting cometary dust halos will also be an indicator of chemical–mineralogical composition and physical properties of mineral particles. The visibility of cometary luminescence is conditioned by the high quantum yield of luminescence and the low albedo of FHP.

2. HYDROCARBONS: CONSTITUENTS OF COMETARY ICE

The spectra of comets, containing emission lines, are also characterized by a faint solar continuum. Ice and dust particles of cometary halos, by scattering optical solar radiation, provide the appearance of such a continuum. Our focus will be on the complex of unidentified emission lines of cometary spectra.

Polycyclic aromatic hydrocarbons (PAHs), widespread in the universe, are also contained in comets (Ehrenfreund & Charnley 2000; Clairemidi et al. 2004, 2007; Lisse et al. 2007). It was proposed by Simonia (2007a, 2007b) that cometary nuclei can contain frozen mixtures of PAHs and alkanes, for example, phenanthrene + *n*-hexane or coronene + *n*-heptane. As the comet approaches the Sun, with intensification of the processes of ice sublimation and mechanical destruction of the cometary nucleus surface layers, the ejection of fine-grained icy particles into near-nucleus space takes place. This process, to a great extent, causes the formation of icy cometary halos of characteristic size and form. Icy halos of comets also contain fine-grained icy particles consisting of a frozen mixture of PAHs and alkanes. Such icy particles can contain additional admixtures as components of solid solutions or mechanical inclusions, for example, inclusions in the form of submicron carbonaceous particles. Fine-grained icy particles, which consist of a frozen mixture of hydrocarbons (FHPs), are contained in the icy halos of comets, and characterized by corresponding sizes and shapes that are micro-fragments of polycrystalline solutions of hydrocarbons, the constituents of icy cometary nuclei.

Solar UV radiation excites the photoluminescence of FHPs of icy cometary halos. UV photons, absorbed by icy particle matter are re-emitted in the form of lower-energy photons within the visible range of the spectrum. Naturally, fluxes of electrons and protons of high energies can also excite FHP luminescence—the process of cathodo-luminescence of icy particles. The spectral composition of FHP luminescence depends on (1) the chemical composition of a concrete icy particle, (2) the PAH concentration of the particle matter, (3) the particle matter temperature, (4) the presence or absence of additional luminescent admixtures in the particle matter, and (5) the solar activity phase. Complex organic mixtures at room temperature are characterized by luminescence spectra in the form of wide structureless bands. Laboratory experiments have revealed that if PAH molecules are dissolved in alkanes at 77 K or lower, aromatic molecules will become isolated from each other and fixed in the solvent. Such a matrix is characterized by luminescence spectra in the form of a series of narrow lines—quasi-linear spectra (Schpolski 1962). In cometary ices, frozen mixtures of PAHs and alkanes may emit narrow luminescence lines at specific heliocentric distances where the ice temperature is around 80 K or lower. Laboratory data point to the fact that FHPs of icy cometary halos can potentially possess photoluminescence spectra (1) in the form of wide structureless bands and (2) containing a series of very narrow lines. The existence of the Schpolski matrix in cometary ices is highly possible due to the low temperature of cometary bodies and the numerous organic compounds in cometary matter.

The detectability of photoluminescence emissions of cometary FHPs is an important factor. Gudipati et al. (2003) proposed that the quantum yield of luminescence of small grains containing organic mixtures varies within 90%–100%. These laboratory data point to bright luminescence of organic mixture excited by UV radiation. We calculated, for conditions of real cometary halos (FHP halos), the ratio of the flux of luminescence to the flux of scattered solar radiation $F_{\mathrm{lum}}/F_{\mathrm{scat}}$. The following conditions were assumed: the FHP was of millimeter size, the chemical composition of the particles was phenanthrene + *n*-hexane, the albedo of the particles was $A = 0.1$, and the FHP luminescence yield was $q = 50\%$. We calculated this ratio for spectrum ranges with different widths and wavelengths using the values of solar UV and optical fluxes at a distance of 1 AU. obtained from different databases and sources, including Cox (2001). The calculations suggested that for the considered FHPs of icy cometary halos the ratio $F_{\mathrm{lum}}/F_{\mathrm{scat}}$ varies within 1.2–4.3. They also suggested that solar UV radiation in the range 3000–3800 Å effectively excites cometary FHP luminescence in the range 4000–7000 Å. This means that in many cases the FHP luminescence signal lies over the scattered solar continuum. This signal represents faint but quite fixed emission. Such relatively faint unidentified emissions are presented in the catalog by Brown et al. (1996) and the atlas by Cochran & Cochran (2002).

The comet 153P/Ikeya-Zhang was discovered in 2002 February. This comet has been studied by Kawakita & Watanabe (2002) and Cremonese et al. (2007). In particular, Kawakita & Watanabe (2002) reported that unidentified molecular bands, observed in the plasma tails of several comets, are found in the antisunward coma of 153P/Ikeya-Zhang. Emissions of methane and ethane were detected in the infrared spectra (Kawakita et al. 2003). The optical parameters of this bright comet have been studied by Hasegawa & Nakano (2003). Jets, shells, and halos of Ikeya-Zhang have been studied by Manzini et al. (2007). They observed the burst which led to the wide expulsion of arc-shaped material that moved across the coma at about 0.35 km s^{-1} and was subsequently scattered. These authors determined the rotation period of the nucleus as 1.48 ± 0.20 days.

The work of Cremonese et al. (2007) contains an extended catalog of emission lines of the spectrum of comet 153P/Ikeya-Zhang. In the catalog, 8468 emission lines were listed. Of these, 1862 emission lines were listed as unidentified. We conducted a comparative analysis of the spectral positions of unidentified emission lines in the spectrum of comet 153P/Ikeya-Zhang with the spectral positions of photoluminescence emission lines of the chemical analogs of cometary FHPs in the form of polycrystalline solutions (PAH+alkanes). For the laboratory data we used the atlas of quasi-linear spectra of luminescence of aromatic molecules and other materials (Teplitskaia et al. 1978; Nakhimovsky et al. 1989; Rima et al. 1999; Ghauch et al. 2000). The criteria for selection were coincidence with spectral positions of the corresponding emission lines to within ±0.5 Å and the similarity of their profiles.

Table 1 shows the results of our comparative analysis. In Column 1, the wavelengths of (observed) cometary emission lines that have the status of unidentified in the catalog of Cremonese et al. (2007) are given. Column 2 presents the wavelengths of luminescence emission lines of polycrystalline mixtures (PAH+alkanes) selected from Teplitskaia et al. (1978), Nakhimovsky et al. (1989), and Rima et al. (1999; laboratory data). Column 3 gives the names of relevant PAHs and relevant aliphatic hydrocarbons. From the analysis, we have

Table 1
Photoluminescence Emission Lines of the Spectrum of Comet 153P/Ikeya-Zhang Comet Spectrum

Observed Lines (Å)	Laboratory Data (Å)	PAHs and Solvents	
4600.98	4601	Perylene	*n*-hexane
4602.14	4602	Phenantrene	*n*-hexane
4602.37	4602	Phenantrene	*n*-hexane
4609.28	4609	Dibenzo[α,h]Pyrene	*n*-hexane
4610.09	4610	Perylene	*n*-hexane
4611.48	4611	11–12-Benzfluorantene	*n*-octane
4614.19	4614	3,4–8,9-Dibenzpyrene	*n*-hexane
4615.39	4615	Triphenylene	*n*-hexane
4617.13	4617	Triphenylene	*n*-hexane
4623.31	4623.3	Perylene	*n*-hexane
4646.13	4646	Triphenilene	*n*-hexane
4649.47	4649	Diphenilenoxid	*n*-hexane
4649.91	4650	Perylene	*n*-hexane
4706.04	4706	Triphenylene	*n*-hexane
4719.17	7419	Tetracene	*n*-hexane
4742.97	4743	1,2–3,4-Dibezpyrene	*n*-hexane
4763.01	4763	2,3-Ortophenylenepyrene	*n*-octane
4769.04	4769	Perylene	*n*-hexane
4769.57	4770	Benzo[j]Fluorantene	*n*-hexane
4794.24	4794	Tetracene	*n*-hexane
4806. 56	4807	Dibenzo[α,h]Pyrene	*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	3,4–8,9-Dibenzpyrene	*n*-hexane
4842.12	4842	Pentafene	*n*-hexane
4849.20	4849	Triphenylene	*n*-hexane
4866.25	4866	Tetracene	*n*-nonane
4874.10	4874	Perylene	*n*-hexane
4874.92	4874.95	Benzo[j]Fluorantene	*n*-hexane
4890.25	4890	3,4–9,10-Dibezpyrene	*n*-hexane
4893.46	4893.3	Benzo[j]Fluorantene	*n*-octane
4897.38	4897	3,4–9,10-Dibezpyrene	*n*-hexane
4915.23	4915	2,3-Orthophenylenepyrene	*n*-octane
4926.31	4926.6	Benzo[α]Fluoranthene	*n*-octane
4937.02	4936.6	Benzo[j]Fluoranthene	*n*-hexane
4950.46	4950	Benzo[j]Fluoranthene	*n*-octane
4966.92	4966.6	Benzo[α]Fluoranthene	*n*-octane
4984.07	4984.3	Benzo[j]Fluoranthene	*n*-hexane
4985.09	4985	Naphtacene	*n*-nonane
5025.12	5025	2,3-Orthophenylenepyrene	*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	1,2–5,6-Dibenzantracene	*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

managed to identify 23 PAH molecules in the FHP matter of icy halos of comet 153P/Ikeya-Zhang: phenanthrene, pyrene, chryzene, and coronene, among others. The analysis suggested, in particular, that 72 lines of the 153P/Ikeya-Zhang spectrum represent photoluminescence emission lines of frozen mixtures of PAH+alkanes, as cometary FHP matter. Photoluminescence emission lines, identified by us, made up 3.8% of the total number of earlier unidentified emission lines of this comet. The remaining 96.2% of emission lines remained unidentified. These lines require further study, considering the high probability of their being ionic.

Thus, the icy halo of 153P/Ikeya-Zhang contains a complex of frozen hydrocarbon particle icy grains of different forms and sizes emitting luminescence in the visual range of the spectrum. In fact, the FHP photoluminescence in the form of phosphorescence and fluorescence occurs with glowing periods $\tau > 0$ and $\tau = 0$, respectively. The cometary luminescence FHP can also be caused by bombarding fluxes of fast electrons of solar origin because solid body photoluminescence and cathodo-luminescence are too alike, differing only in the means of transferring the exciting energy to the corresponding body. We note that five photoluminescence emission lines of the spectrum of 153P/Ikeya-Zhang coincide in spectral position with photoluminescence emissions of the spectra of comets 109P/Swift-Tuttle and 23P/Bronsen-Metcalf. This result supports the similarity of the chemical composition of FHP icy halos of these comets. Thus, FHPs of different cometary icy halos in general, and ices of their nuclei, can be very close, and similar in chemical composition (by chemical composition we understand the composition of the mixture of PAH+alkanes).

Figures 1–3 show relevant fragments of the spectra of 153P/Ikeya-Zhang and 109P/Swift-Tuttle and luminescence spectra of laboratory analogs of cometary FHP matter in the form of a frozen mixture of perylene with *n*-hexane. Attention is drawn to the resemblance of profiles of earlier unidentified cometary emission lines to those of luminescence emission lines of frozen matter of the chemical composition mentioned above. The concentration of aromatic molecules in the mixture within 10^{-3}–10^{-2} mol L^{-1} provides information on luminescence quasi-lines and probably on the detectability of such luminescence in cometary spectra.

Layers of the cometary nucleus may contain relict matter, which has never been processed (irradiated) by solar electromagnetic and corpuscular radiation. Such relict matter probably preserves the main properties from the period of solar system formation. Active phenomena such as jets might serve as a delivering mechanism of the relict into the cometary coma. Relict matter in the form of icy particles, including FHPs, may

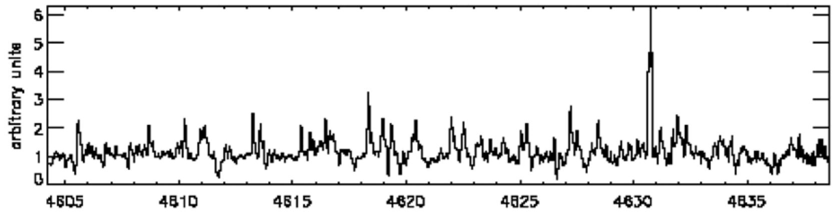

Figure 1. Fragment of the spectrum of comet 153P/Ikeya-Zhang obtained by means of the 3.5 m TNG telescope and echelle spectrograph SARG, La Palma, Canary Islands, Spain (Cremonese et al. 2007). The emission line at 4610 Å was previously unidentified. We now consider it to be a candidate for the luminescence emission line of frozen hydrocarbon particles of the icy cometary halo.

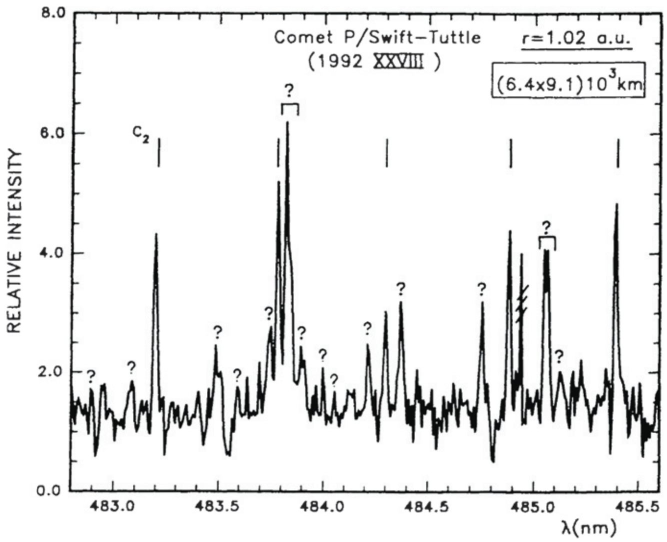

Figure 2. Fragment of the high-resolution spectrum of comet 109P/Swift-Tuttle (Arpigny 1995). The emission line at 483.5 μm was previously unidentified. We now consider it to be a candidate for the luminescence emission line of cometary FHPs.

intensively luminesce in the field of solar ultraviolet radiation. The detection and identification of such luminescence emission will allow us to determine (1) peculiarities of the physical properties of the relict and (2) its exact chemical composition. Comets of the solar system with orbital eccentricity $e < 0.9$ and comets from the interstellar medium with $e > 1$ will probably have different spectral luminescence positions and profiles. Such spectral differences "reflect" those of cometary body origins and their current evolutionary stages. We presume that the discovery of these phenomena will require comprehensive studies of the comets, a long-term observation program, and continued use of the same optical instruments will be required.

3. COMETARY FHP LUMINESCENCE IN THE UV RANGE

If FHPs of icy cometary halos emit luminescence in the visible spectral range, they can also emit luminescence in the UV under the influence of much shorter-wavelength electromagnetic solar radiation. With the aim of proving this supposition, we have conducted a comparative analysis of the spectral positions of the unidentified emission lines of some comets presented in the work of Arpigny (1995) with the spectral positions of luminescence emission lines of FHP chemical analogs (Teplitskaia et al. 1978). Unidentified emission lines were positioned within the range 3180–3315 Å. The analysis was conducted with an accuracy of ±0.5 Å, and the obtained results are given in Table 2. Column 1 gives, the wavelengths of the unidentified cometary emission lines according to Arpigny (1995); Column 2 shows the wavelengths of luminescence emission lines of frozen mixtures of PAH+alkanes (Teplitskaia et al. 1978). Column 3 gives the names of PAHs and solvents, and Column 4 shows the wavelengths of the exciting radiation. On the basis of this analysis, we have managed to identify several PAHs constituting icy mixtures with corresponding aliphatic hydrocarbons. FHPs of the chemical composition of icy halos of the corresponding comets might be the sources of three luminescence emission lines in the UV spectra of these comets. Thus, hydrocarbon particles of icy cometary halos may also luminesce in the UV range.

Table 2
Ultraviolet Luminescence of FHPs in Cometary Halos

Unidentified Emissions (Å)	Luminescence Emissions (Å)	PAHs and Solvents	Excitation Radiation (Å)
3184	3184	Diphenileneoxid *n*-heptane	2850
3290	3290	β-Metilnaphtalene *n*-hexane	3000
3310	3310	Naphtalene *n*-pentane	3000

Clairemidi et al. (2004), studied the P/Halley comet spectrum (obtained by the apparatus Vega 2) in particular, the UV range of this spectrum. Emissions at 3710 Å, 3760 Å, and 3820 Å were identified as fluorescence of PAH molecules, namely, pyrene C16H10. Clairemidi et al. call their identification experimental and preliminary, and it requires further confirmation.

We carried out a comparative analysis of the spectral positions of the UV emission lines of the P/Halley comet spectrum (Clairemidi et al. 2004) with the spectral positions of photoluminescence emission lines of frozen mixtures of PAH+alkanes—the chemical analogs of cometary FHPs. For this, the atlas of luminescence spectra of aromatic molecules was used (Teplitskaia et al. 1978). The analysis was conducted with an accuracy of ±0.5 Å. As a result, it was suggested that the emission line at 3820 Å is the photoluminescence of cometary FHPs of frozen mixtures of pyrene C16H10 and *n*-hexane. The emission lines at 3710 Å and 3760 Å remained unidentified. In the P/Halley comet spectrum, the emission at 3820 Å possesses a noticeable width uncharacteristic of luminescence emission lines of frozen mixtures of PAH+alkanes. Such differences in bandwidth are probably caused by different phases of substances (fluorescence of PAH molecules in gas phase and luminescence of the same frozen PAH).

4. DISCUSSION

We have revealed that from the total number of unidentified emissions of the spectrum of comet 153P/Ikeya-Zhang 72 lines exhibit photoluminescence. Under the influence of solar ultraviolet radiation, 23 PAHs and alkanes in the form of frozen mixtures, constituting icy halo particle matter, may luminesce in the optical spectral range, as the source of a narrow line series.

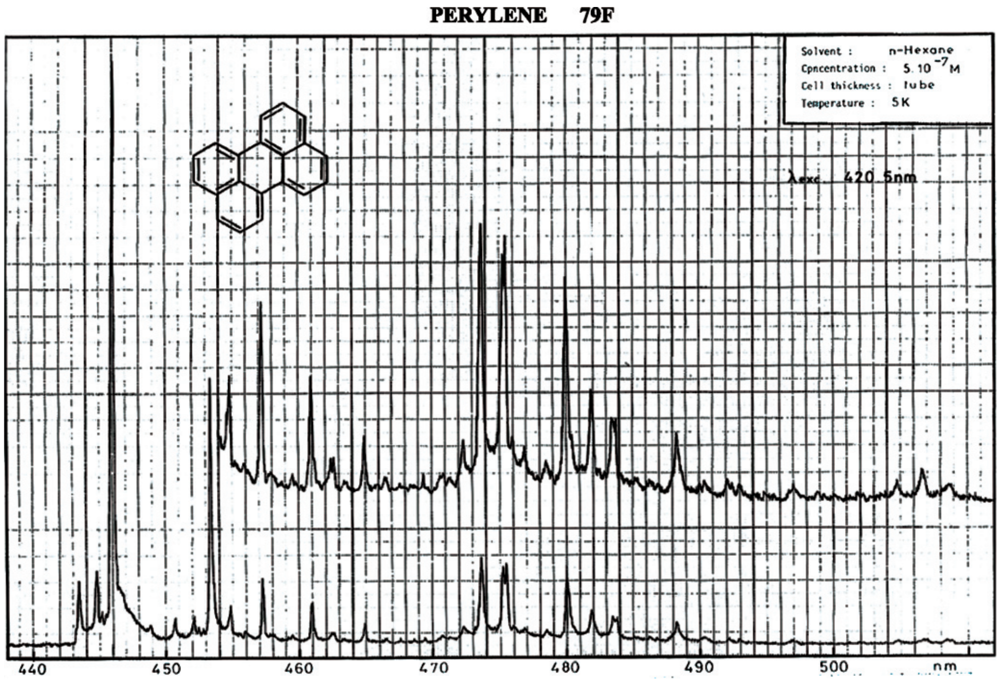

Figure 3. Fragments of luminescence spectra of a frozen mixture of perylene and *n*-hexane (Nakhimovsky et al. 1989). Emission lines at 461 μm and 483.33 μm coincide in the spectral position with cometary unidentified emissions (Figures 1 and 2). Different concentrations of aromatic molecules in cometary and laboratory samples provide differences in bandwidth in astronomical and laboratory spectra.

Thus, the icy halo of this comet abounds in organic compounds in the form of frozen aromatic and aliphatic hydrocarbons. The study of the luminescence of cometary ices enables us to determine their exact chemical composition and, in some cases, their temperature.

The presence of noticeable organic components in cometary ices in the form of hydrocarbon mixtures indicates that other icy bodies, including ice-covered bodies (some satellites of giant planets), can luminesce under the influence of short-wavelength solar radiation and fluxes of solar wind charged particles. This means that detection of such luminescence and correct interpretation of the obtained data enables us to at least determine the chemical composition of these bodies.

We have also studied the UV components of other cometary spectra and propose that a number of their unidentified emission lines represent UV luminescence of FHPs. Unfortunately, non-uniformity in laboratory data creates noticeable limitations on the accuracy of the comparative analysis. Laboratory data, as a rule, are obtained during experiments conducted under different conditions, with varying accuracy, and on different equipment. Authors working in the fields of photochemistry and oil chemistry often publish their data in fragments rather than in full. Different materials cannot always combine and react. That is why it is expedient to prepare and conduct directed laboratory experiments on the modeling of cometary FHP excitation and detection of its luminescence. Such experiments will enable us to form a purpose-oriented comparative basis, required for the identification of icy cometary halo luminescence.

Surfaces of icy cometary nuclei can also luminesce under the influence of solar short wavelength radiation. This may happen only at great heliocentric distances in the absence of cometary halos. Instrumental detection of the possible luminescence of cometary nuclei will be quite a difficult task, taking into consideration the great geocentric distance of "naked" cometary nuclei.

Simonia (2005) carried out comparative analysis of photoluminescence spectra of laboratory analogs of FHPs with the spectrum of comet 122P/de Vico (Cochran & Cochran 2002) characterized by the presence of numerous unidentified emissions. The atlas of quasi-linear luminescence spectra of aromatic molecules (Teplitskaia et al. 1978) and other sources of photochemical data served as the laboratory material. The spectrum of comet 122P/de Vico studied by Cochran & Cochran (2002) served as the observational material. Table 3 gives some results on the identification of the emissions of the spectrum of 122P/de Vico not previously identified. The first column gives the names of PAHs, the second column gives the names of the corresponding solvents, the third column gives the wavelengths of photoluminescence emissions of the frozen mixture of PAH + alkanes (laboratory data), and the fourth column gives the wavelengths of earlier unidentified emissions of the spectrum of 122P/de Vico. The FHP halo of this comet is the source of numerous photoluminescence emissions in the range 3800–6700 Å. Table 3 contains FHP photoluminescence lines, which coincide well in wavelength with those of the 153P/Ikeya-Zhang spectrum. In fact, the 153P/Ikeya-Zhang and 122P/de Vico spectra show 40 similar photoluminescence emission lines of FHPs. This means that, in different comets, FHPs of icy halos may have similar chemical composition.

Based on the above analysis, the following initiatives are proposed: (1) it would be reasonable to create an electronic database of unidentified cometary emissions and (2) it should be possible to publish the most recent data on unidentified cometary emissions (in the form of separate tables). To realize these initiatives, it would be necessary to have spectral data obtained by different observers and their groups from the implementation of different projects and programs.

The creation of an electronic database of unidentified cometary emissions and the publication of the tables of such emissions will allow us unify and to accumulate the scattered

Table 3
Photoluminescence Emission Lines of the
Spectrum of Comet 122P/de Vico Comet Spectrum

PAHs	Solvent	Photoluminescence Emissions (Å)	Unidentified Emissions (Å)
Pyrene	*n*-hexane	5894	5893.85
		6027	6026.66
		6036	6036.42
		6509	6508.71
1,2-Benzpyrene	*n*-hexane	5349	5349.22
		5366	5366.02
		5479	5479.25
Tetraphene	*n*-hexane	6415	6415.14
		6638	6638.21
1,2–5,6-Dibenzantracene	*n*-hexane	5542	5542.40
		6096	6096.48
		6135	6135.00
Tryphenylene	*n*-hexane	4615	4615.39
		4617	4617.14
		4646	4646.15
		4706	4706.03
		4849	4849.20
Phenantrene	*n*-hexane	4602	4602.14
		4602	4602.37
Chrysen	*n*-hexane	5060	5060.23
		5028	5028.42
		5318	5318.08
1,12-Benzperylene	*n*-hexane	6151	6150.94
Pentaphene	*n*-hexane	4842	4842.12
Coronene	*n*-hexane	5260	5260.31
		5615	5615.23
		5630	5629.74
3,4–9,10-Dibenzpyrene	*n*-hexane	4890	4890.01
Perylene	*n*-hexane	4601	4600.98
3,4–8,9-Dibenzpyrene	*n*-hexane	4840	4840.06
2,3-Orthophenylenpyrene	*n*-hexane	4915	4915.23
		5025	5025.12
	n-octane	4763	4763.03
Tetracene	*n*-hexane	5087	5086.61
		4719	4719.17
		4794	4794.01
	n-nonane	4866	4866.26
		5176	5176.26
		5197	5197.21
		5219	5218.65

data, which, in turn, will stimulate further investigations in this field.

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.

5. CONCLUSION

We have described the peculiarities of FHP photoluminescence of icy cometary halos. A comparative analysis was conducted on spectral positions of unidentified emissions of the spectrum of comet 153P/Ikeya-Zhang given by Cremonese et al. (2007) with luminescence emissions of FHP analogs given by Teplitskaia et al. (1978) and Nakhimovsky et al. (1989). Seventy-two emissions of the 153P/Ikeya-Zhang spectrum were proposed as photoluminescence of icy halos of this comet and 23 PAHs as components of FHPs of icy cometary halos. Luminescence of cometary FHPs in the UV range was revealed. Luminescence of icy particles of the halos of comets can become a new channel of information on cometary relict matter. 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 bioastronomy.

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