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Optical and infrared observations of solid state interplanetary matter

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Doctoral thesis

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Optické a infračervené projevy meziplanetární látky v pevném stavu

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Předseda oborové rady F1	Prof. RNDr. Jiří Bičák, DrSc. Katedra teoretické fyziky MFF UK V Holešovičkách 2, Praha 8

Contents

1 Preface

When I finished my work on the Master's thesis I wished to continue research in a related topic. My Master's thesis was based on measurements of space probes to Comet Halley. So I was very happy that I could concentrate on infrared observations of comets based on data from Infrared Space Observatory as the topic of my PhD thesis. I found this work very interesting especially due to possibility to join the big, international project.

I started my PhD studies in October 1993 by improving my background in infrared astronomy and studying theoretical aspects of the problem. But ISO launch was delayed and waiting for observational data made that the subject — IR appearance of dusty comae — came out of the time limits for my PhD Thesis.

So, I gladly accepted an opportunity to work on programme of television observations of meteors — in the group I was before collaborating with. In September 1994 I joined Astronomical Institute, Academy of Science of the Czech Republic in Ondřejov — department of interplanetary matter. I have been working on data processing in TV meteor spectroscopy.

ISO successfully launched on November 17, 1995 and important results have been received till May 16, 1998, when satellite was switched off. But in that time my main work was already TV spectroscopy of faint meteors and I found this topic so exciting that I did not interrupt it when the ISO data begun to be available.

Thus the main method of investigating the meteoroidal matter of cometary origin became the optical spectroscopy of shower meteors accompanied by IR photometry of some comets.

2 TV spectroscopy of meteors

2.1 TV observation

If we wish to study a faint interplanetary material we have either to make the observations of its scattered and thermal radiation, or to collect samples of it (IDPs and or in situ measurement of probes to Comet Halley), or to record the spectrum of the meteoric light.

In the last case only large bodies (fireballs) can easily be recorded photographically, but fireballs are a phenomenon too rare to be used for statistical comparative studies. This drawback can be eliminated by using a more sensitive television equipment which is capable of recording of large number of spectra of smaller particles than the photography.

Another advantage of the use of television techniques instead of classical photographic method is the good temporal resolution. On the other hand, the spatial resolution is lower.

The TV spectroscopy of meteors was started by the pioneering work of Millman et al. (1971). Further successful observations were performed in Ashchabad (Mukhamednazarov and Maltseva 1989). However, in general, relatively small attention has been devoted to this subject.

Now TV (mainly non-spectroscopic) observations are performed by International Meteor Organization, Nippon Meteor Society, Kyiv University in Ukraine, R. Hawkes' group in Canada.

At the Ondřejov Observatory, regular TV observations of meteor spectra started in 1990, so that the number of registered spectra is large enough for processing by statistical methods.

2.2 Observed interplanetary material

The TV technique can record spectra of meteors brighter than +3 mag. The mass of a particle which cause the +3 mag meteor is about 10^{-6} kg = 0.001 g (Spurný 1991). Such particles originate in cometary nuclei (in the case of shower meteors) and their higher concentration can be expected in coma. However, these particles in coma can be observed only in far infrared spectral range where they emit the thermal radiation, while the scattered light by those particles is lost in the bright shine of the coma dust. The range of ISOPHOT photometry (see Section 7.2) allows however to detect also those larger particles.

2.3 Expected features

Hypotheses about features that we can expect in our TV meteor spectra were listed in several recent papers:

Components in meteor spectra (Borovička 1994): "Through an analysis of fireball spectra it was found that meteor heads consist of two parts with quite different temperatures. The spectra of both parts can be fitted with a simple thermal equilibrium model. The temperature of the main spectrum is about 4 000 K, and that of the second spectrum is about 10 000 K. There is little evidence for a dependence of temperatures on the meteor velocity. However, the mass and luminosity of the second part relative to the main part grows rapidly with meteor velocity. The high temperature part forms only 0.02 % of the meteor vapor envelope in slow meteors but accounts for more than 5 % in fast meteors. ... This region is very probably related to the meteor shock wave."

Our set of spectra of meteor showers of various velocities allows to study the above mentioned dependence of luminosity of the second spectrum on the meteor velocity.

Unique composition of α Monocerotids (Jenniskens et al. 1996): "... The double–station observations also provide clues regarding the structure of the dust particles within the α Monocerotid stream. They penetrate deeper into the atmosphere than meteoroids of the Orionid stream (P/Halley) or Perseid stream (P/Swift–Tuttle) and the light curves of the meteors do not show flares."

The Jenniskens' results imply that α Monocerotids are more compact than other showers meteoroids probably due to a lack of volatile elements, and our α Monocerotid spectra seem to be consistent with this hypothesis.

3 TV meteor observations in Ondřejov

TV meteor observations started in Ondřejov in 1990. During six years of regular observations tens of meteors and also more than one hundred of meteor spectra were recorded. Recording of meteor spectra is the main part of TV observation programme in the last years.

The first TV observations were prepared and made by Dr. Vladimír Padevět and Jaroslav Boček. Their work were supported by Grant Agency of the Czechoslovak Academy of Sciences, grant no. 30351 — Relation of meteorites to comets (1992–1994; V. Padevět, J. Borovička, J. Boček). Since 1994, after the sudden death of Dr. Padevět, Dr. Borovička became new leader and grant principal investigator. Current team members are Dr. Jiří Borovička, Jaroslav Boček, Jaroslava Keclíková, Rostislav Štork and also non–spectral part of the team: Dr. Pavel Spurný, Dr. Jaroslav Rajchl, Pavel Koten.

3.1 Spectral sensitivity

The sensitivity of our detector as a function of wavelength is known, the spectral sensitivity curve was obtained by the observation of spectra of bright standard stars and is published in (Borovička & Boček 1995). However, when the spectrum is divided by the spectral sensitivity curve, it produces a noise increase on the spectrum edges and results in an unrealistic 'parabolic' shape of the spectrum. Thus we decided not to calibrate the observed spectrum as a whole.

On the other hand the measured line intensities can be calibrated by using spectral sensitivity at the corresponding wavelengths. So, the spectra in Section 4 are not calibrated, but the line intensities in Section 5 are.

3.2 Recorded spectra 1990–1994

The results in the following Sections are based on the evaluation of TV spectra captured during the period 1990–1994. This group is the first one in Ondřejov programme which is enough numerous for statistical processing. Also, the α Monocerotids spectra (captured 21/22 XI 1995) were added to this group as a sample of interplanetary material of a distinct composition.

The quality of some faint meteor spectra is bad and a spectrum part with only one line is often recorded. These spectra cannot be used for the comparison of lines intensities and presence.

Thus we selected 44 good quality TV spectra which are usually recorded on several images with a time step of 0.04 s. The time evolution shows significant changes in a meteor spectrum and that is why we prefer to process more images rather then averaging them.

4 High quality spectra of cometary meteors

The examples of high quality spectra are shown in this Section, but we selected more spectra (all with at least two recognized lines) for further analysis.

Perseids Perseids are the most frequent among our set of spectra, about one half of all. Even if error bars of other showers are smaller or zero, the points representing the Perseids on Fig. 5 are the best defined and other showers can be related to them. The velocity of Perseids is 61 km/s.

Orionids Orionids' characteristics are similar as Perseids' ones. Their velocity is 67 km/s (Perseids 61 km/s) and both showers come from well known comets. Also our spectra don't show exceptional differences.

TVS 74 The spectrum on Fig. 1 contains all of features described in the previous subsections. It means bright lines Mg I-2 (517 nm), Na I-1 (589 nm) and O I-1 (777 nm), fainter lines O I-10 (616 nm), Fe I-168 (650 nm), N I-3 (745 nm) and three N_2 belts (570–600 nm, 635–670 nm, 730–760 nm) are recorded.

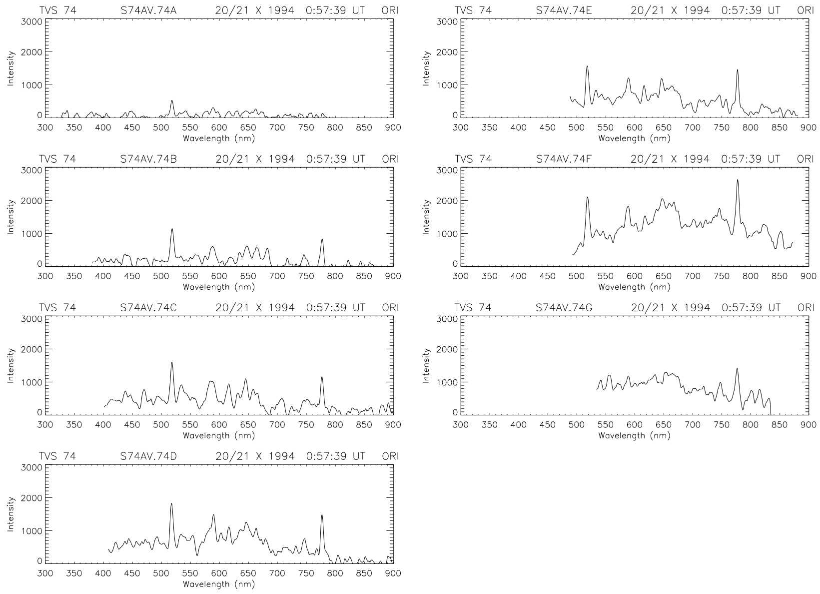

Figure 1: Orionid spectrum TVS 74

CN bands were also recorded in this spectrum. They are overlapped with N_2 bands in the best images, but in the first images where atmospheric belts are enough faint they can be recognized. In the plot `S74AV.74B` you can see three belts on approx. 645 nm, 665 nm and 682 nm. The CN bands are significantly narrower than those of nitrogen.

Geminids Geminids are slow meteors with the velocity of 36 km/s. It means their spectra should show lower intensities of the second spectrum lines (especially O I-1 (777 nm)). In addition the Geminids are known to come from the asteroidal body (3200 Phaeton) that indicates lower amount of volatile elements in these meteoroids.

Quadrantids Quadrantids are represented by only one point in Fig. 5 and we cannot make any conclusions about the entire shower. Nevertheless, our Quadrantid spectrum corresponds with linear dependencies on Fig. 5. The velocity of Quadrantids is 42 km/s.

δ **Aquarids** δ Aquarids is another less populated shower in our set. Likewise Quadrantids the recorded δ Aquarids also can't give reliable results but they follow the general dependencies. The velocity of δ Aquarids is 44 km/s.

α **Monocerotids** Although the aim of our work is a complete processing of collection 1990–1994 of Ondřejov TV meteor spectra we decided to add spectra from November 22, 1995 to our set. During that night α Monocerotids outburst was observed and several, at least four spectra were taken; in other cases the identification is not sure.

We suppose that α Monocerotids have lower amount of volatile elements (Section 2.3) and so our spectra represent a sample of interplanetary material with a specific composition. They also bring new entries into a statistics in Section 5.

The velocity of α Monocerotids is 64 km/s but their spectra look unlike Perseids (61 km/s) and Orionids (67 km/s). The hypothesis con-

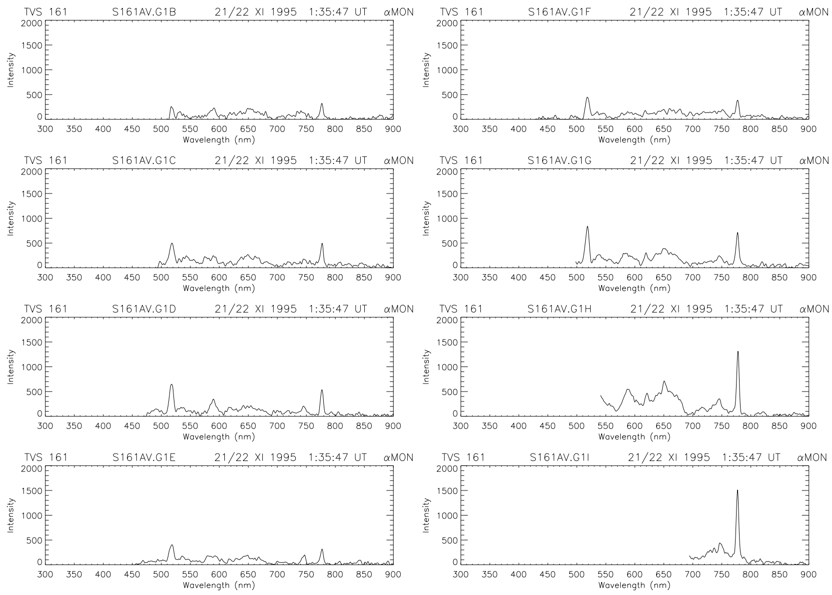

Figure 2: α Monocerotid spectrum TVS 161

cerning low amount of volatile elements (Section 2.3) is confirmed. The sodium line Na I-1 (589 nm) is very faint in all α Monocerotid spectra.

TVS 161 TVS 161 is our brightest α Monocerotid spectrum taken during the 1995 outburst. The prominent lines on Fig. 2 are Mg I-2 (517 nm) and O I-1 (777 nm). Although the N_2 belts (570–600 nm, 635–670 nm, 730–760 nm) and the faint lines O I-10 (616 nm), Fe I-168 (650 nm), N I-3 (745 nm) are visible the intensity of Na I-1 (589 nm) is very low.

Very slow meteor TVS 73 The duration of TV meteors is usually several tenths of second. TVS 73 represent the only exception in our set of Ondřejov TV spectra. We have recorded 30 images with the step of 0.04 s. Our field of view is 10×10 degrees, so the angular velocity was about 10 degrees per second. Elevation was about 45°. Assuming the height was about 80 km we can estimate the lower limit of the meteor velocity. It is about 20 km/s.

Typical features of this slow meteor spectrum are the high ratio of mineral over atmospheric lines (main spectrum over second one) and also high Na/Mg ratio probably caused by higher excitation potential of Mg I-2.

5 Statistically significant differences in observed spectra

5.1 Set of studied spectra

As mentioned in the Section 3.2 we choose 44 good quality spectra with several images of each. Our set consist of 17 Perseids, 5 Orionids, 5 Geminids, 1 Quadrantid, 2 δ Aquarids, 4 α Monocerotids, 10 sporadic meteors included very slow meteor TVS 73.

5.2 Intensity plots

The spectra of which examples are shown in Section 4 contain several lines. However only four lines were found to be enough bright in the significant number of recorded spectra and can be used for statistical processing.

We measured spectrum intensity at wavelengths 517.8 nm (Mg I), 589.2 nm (Na I), 746.8 nm (N I) and 777.4 nm (O I). The intensity is produced by scanning pixel intensities of the recorded image and is given in the relative units only.

The measured values were calibrated by spectral sensitivity curve of our technique (see Section 3.1).

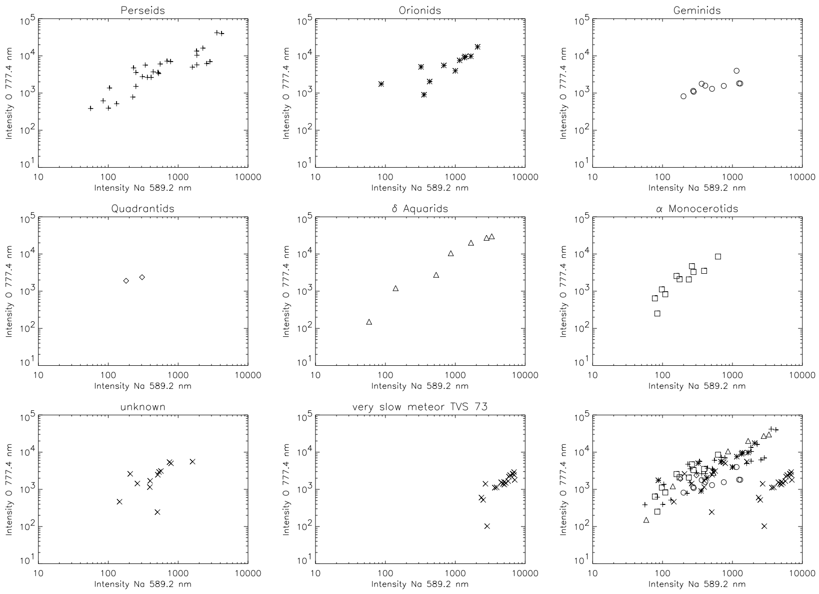

Figure 3: Na and O intensities in the studied spectra

Na and O intensities The points on Fig. 3 fall on one line because the meteor spectra show the correlation of intensities of Na and O lines. However, some differences between showers are apparent.

The O I-1 line is fainter in spectra of slower meteors (Geminids and very slow meteor TVS 73). It's probably caused by a strong dependence of the brightness of the second spectrum (which O I-1 belongs to) on the meteor velocity (see Section 2.3).

On the other hand, α Monocerotids have lower amount of sodium and so the corresponding points on Fig. 3 are shifted to the left.

Mg and O intensities Plots on Mg–O graphs show linear dependence in individual showers, but they differ in the line slope.

As mentioned in the previous subsection the amount of the second spectrum is lower in slow meteors. That is why the Geminids plots are shifted to the right and down. The shift of another slow meteor TVS 73 isn't so clear because both of Mg and O lines are very faint and affected by noise.

Mg and Na intensities The most important features of Fig. 4 are:

- The Geminid points are shifted to the right. Geminids are known to have lower amount of volatile elements because they originate from asteroid [(3200) Phaeton].
- The Mg I-2 intensity is low in the slow meteor spectrum TVS 73. It may be caused by higher excitation potential of this line (Mg I-2 2.72 eV, Na I-1 0.00 eV[1]). In case of higher velocities, both lines are saturated and optically thick and this phenomenon isn't important.

O and N intensities The O I-1 and N I-1 lines are both atmospheric and both belong to the second spectrum. So the correlation between those lines is the strongest one of all plotted combinations and the points on the graph represent an almost perfect line.

[1] <0.005 eV

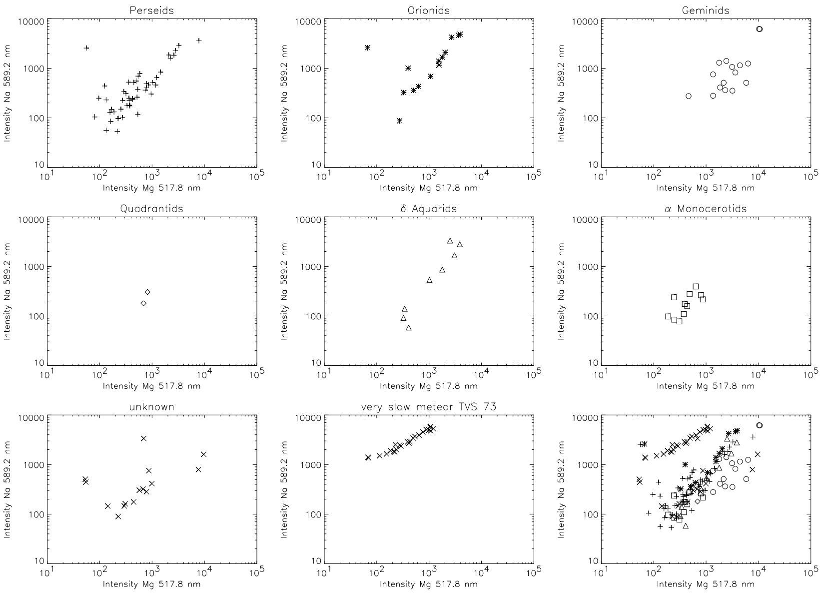

Figure 4: Mg and Na intensities in the studied spectra

5.3 Selected images

All good quality images were used for the previous plots (Figs. 3 and 4) and a spectrum is represented by several points of the corresponding time steps. For further analysis we selected the best image of each spectrum. The use of selected images in the previous plots doesn't give good results. The points in the lower left part of the diagrams disappear because they represent fainter intensities in the first or final time steps.

Nevertheless we can use the selected images for estimating the ratios of line intensities. The most interesting plot is the velocity dependence of those ratios.

Of course, sporadic meteors were not included in plots on Fig. 5 because the velocity is known only for shower meteors. Only in the case of the extraordinary slow meteor TVS 73 we estimated its velocity (see Section 4).

5.4 Dependence on velocity

The use of weighted[2] averages with standard deviation bars would be correct but it will not show how many spectra were averaged and how significant shower value is. Thus I find Fig. 5 to demonstrate better the dependence.

The Na/O ratio decreases with increasing velocity. All showers are in compliance with this relation except α Monocerotids. The differences in α Monocerotids spectra aren't caused by velocity and so they indicate rather differences in the meteoroidal composition.

The Mg/O plots don't show clear relation. Geminids are known to have a bright Mg line. But the TVS 73 point is not sure because, as mentioned in the subsection 5.2, both lines are faint and the signal/noise ratio is very bad. In addition, Mg excitation potential phenomenon (see subsection 5.2) probably influences this plot too.

The relation of Na/Mg ratio on the velocity should be divided into two parts. In case of slow meteor Mg line isn't saturated and is optical thin (also see subsection 5.2). In that velocity range Na/Mg ratio

[2]the weight is the intensity of lines — meteor brightness

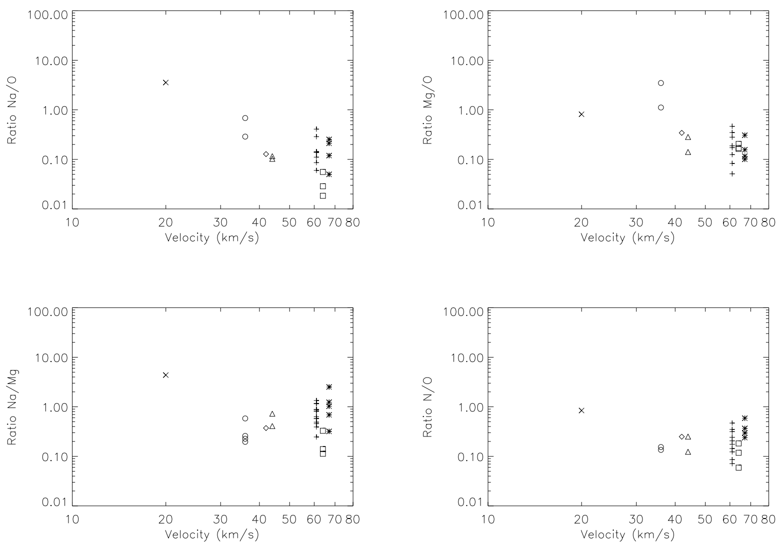

Figure 5: Dependence on velocity — all spectra

decreases with increasing velocity. In the second part both lines are saturated and optically thick. Here Na/Mg ratio slightly increase with increasing velocity. The low amount of sodium in the α Monocerotids spectra is already mentioned.

The ratio N/O should be constant, independent on velocity, and this is approximately fulfilled. The TVS 73 point is uncertain, because the N line is very faint in this spectrum and thus affected by the noise.

6 Results from TV meteor spectra

In our work we have proceeded all TV meteor spectra recorded at the Ondřejov Observatory in the time period 1990–1994. The 44 spectra which contain more than one line were selected for further analysis and statistical processing.

Our hypotheses mentioned in the Section 2.3 are confirmed and the expected features were really found. Also, we obtained other interested results:

6.1 Components in meteor spectra

Plots in Section 5 indicate differences between fast and slow meteors mentioned in Section 2.3.

The brightest lines of second spectrum are N I-3 (745 nm) and O I-1 (777 nm). Incidentally, whereas the bright lines of the main spectrum is a radiation of the mineral, meteoritic material, the N I-3 (745 nm) and O I-1 (777 nm) lines are atmospheric. Thus the variation of ratio of second spectrum lines is small, because the composition of Earth atmosphere is the same in all cases. But the ratio of main spectrum lines varies due to the different elemental abundance in meteoritic material.

The dependence of intensities ratio on velocity (plots on Fig. 5) shows interesting trends:

1. The most prominent one is decreasing trend of Na/O ratio, which confirm higher intensity of second spectrum in high velocity meteors.

2. Also Mg/O plots show similar trend but affected by the anomalous value of Geminids.
3. The Na/Mg case is a more complicated and the dependence should be divided into two velocity ranges. See Section 5.4.
4. N and O are both atmospheric lines and both become to the second spectrum. The N/O ratio should be constant and roughly speaking it is.

6.2 Peculiar features of α Monocerotids

Jenniskens et al. 1997 found that α Monocerotids penetrate deeper into the atmosphere than meteoroids of the Orionid stream or Perseid stream (meteoroids with similar velocity) and that their light curves do not show flares. The Jenniskens' results imply that α Monocerotids are more compact than other showers meteoroids and can therefore contain lower amount of volatile elements. (Section 2.3).

Our spectra show very low abundance of Na in all recorded α Monocerotid spectra (Sections 4 and 5.4) and the hypothesis concerning low amount of volatile elements could be confirmed, at least for sodium.

6.3 Peculiar features of Geminids

The parent body of Geminids is the asteroid (3200) Phaeton. So, they are supposed to be compact and have lower amount of volatile elements too. But unlike α Monocerotids (64 km/s) their velocity is only 36 km/h and the spectra should show high ratio of main/second spectrum intensity.

Our Geminid spectra really show high intensity of Mg I line (517.8 nm) relatively to the second spectrum (O I (777.4 nm)). Another main spectrum line Na I (589.2 nm) is not so bright and it is probably caused by specific Geminids composition and origin.

See Sections 4, 5.2, and 5.4.

6.4 Detection of CN

Detection of CN bands on the photographs is very complicated and CN bands aren't surely demonstrated. The reasons are:

1. The dispersion of photographic spectra is high and allows to detect individual band lines. That lines are faint and lower dispersion of TV spectra is an advantage here. The individual lines aren't recognized and the cumulative brightness of band is higher.

2. It's hard to detect CN bands by observation without temporal resolution. On photograph CN bands are overlapped by N_2 bands and other lines. The TV technique allows to obtain a spectrum in the specific moment when CN bands are the brightest feature in spectral range.

We found one spectrum where CN bands are recorded, it demonstrates well the advantage of the TV recording technique. See Section 4 — TVS 74.

6.5 Plans to the future

This work is based on the TV meteor spectra observed in 1990–1994 (plus α Monocerotids outburst 1995) which represent about one half of the spectra taken until now.

So, our challenge is a digitizing and reducing of remaining spectra. We will have doubled number of data in our statistics and it should improve the credibility of our results.

Ondřejov TV programme does not consist only of spectroscopy but also of simultaneous observation together with data collected by telescopic observers or radar and double–station observations were performed. That material could contain interesting phenomena and their investigation could bring new results.

At present we have three cameras and we plan to observe simultaneously at two stations, making the spectral observation in Ondřejov and white light records at both stations in Ondřejov and Kunžak.

7 Infrared spectra, color temperatures and composition of cometary dust

7.1 Comets in infrared

The infrared spectrum of comets consist in general from two parts — the region above 1 μm is dominated by the solar spectrum scattered by the about 1–10 micron–sized dust in coma, and the thermal radiation of this dust has its maximum at larger wavelengths depending on heliocentric distance of the comet.

Dust grains smaller than about 0.5 μm can not radiate effectively on longer wavelengths and so they became overheated by several tens to one hundred Kelvin when compared with the equilibrium black–body temperature at the given heliocentric distance. Larger particles, till those comparable with micrometeoroids registered in showers, have temperatures close to equilibrium but their contribution to the thermal radiation of coma could be substantial only at longer wavelengths. Thus, the thermal continuous spectrum of a coma is a mix of Planck curves of different temperatures, which is nearly planckian. The real cometary spectrum shows moreover several emission bands at 8–13, and 20, 24 μm, that are caused by silicates in grains.

Data in the long wavelength IR were obtained by IRAS (Infrared Astronomical Satellite — 1983) and now by ISO (Infrared Space Observatory) that was operating from November 1995 to April 1998.

Some preliminary methods were developed in this thesis to simulate the thermal radiation of coma and to compare it with the observed data.

7.2 ISOPHOT observations

Infrared photometrical observations of several comets and cometary–like objects were included in the Guaranteed time programme by ISOPHOT: 29P/Swassmann–Wachmann 1, 22P/Kopff, (2060) Chiron; and the comet C/1995 O1 Hale–Bopp became a very suitable bright object of the Target of Opportunity programme. Most of the photometric observations were accompanied by SWS/LWS spectrometry as close as possible to the observing dates of ISOPHOT. Unfortunately the great comet of the year 1996 Hyakutake could not be observed due to its fast proper motion.

The sequence of ISOPHOT observations consisted of photometry with some of broad–band filters 3.6, 7.3, 10, 12.8, 16, 25, 60, 100, 160 μm, using several apertures at 16 and 25 μm filters; and chopping between the comet and internal calibration heat source. In order to extract the infrared background, one more observation was done at the same position with the same filters, apertures and exposure times, but some days later, when the comet already moved to another place (so called shadow observation).

Comet Kopff We processed ISOPHOT observations of Comet Koppf on March 6 and 14, 1996 and fitted the Planck curves on the measured values.

Comet Kopff was observed not only by ISOPHOT, the observations were also performed by other instruments (ISOCAM) and the cometary trail was detected. The Kopff trail was observed close to the maximum visible brightness of the comet, at 4 distances from the nucleus along the cometary path: -2 degrees, $+0.25$, 2 and 5 degrees. Scans at these distances perpendicular to the trail were performed.

Cometary trails were found for the first time on IRAS pictures in 1983, they resemble wires in the space along the cometary orbits. As it was soon interpreted, they consist of millimeter to centimeter sized solid particles released from cometary nucleus. Since these particles are much larger than the dust in coma, they are not influenced comparatively by the solar radiation pressure and they remain in the interplanetary space near to the orbit of their source comet.

The millimeter to centimeter sized particles are the ones which cause the faint meteors observed by TV technique (spectroscopy) as described in the previous Sections.

Comet Hale–Bopp Comet Hale–Bopp was the great comet of 1997. The early discovery and its strong activity at large heliocentric distance provided a rare opportunity to observe the dust over a wide range in solar heating.

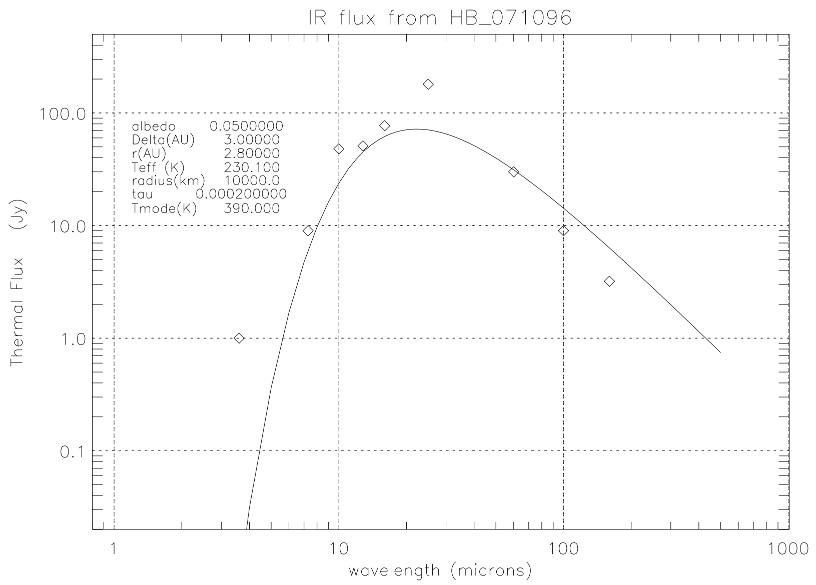

Figure 6: Comet Hale–Bopp, October 7, 1996

Comet Hale–Bopp were observed by ISOPHOT on March 25, 1996; April 28, 1996; September 27, 1996; October 7, 1996 and December 30, 1997. We processed those observations and fitted Planck curves on the measured values. Figs. 6 and 7 show the examples of our fits. Parameters of curves are listed in the figures. In the case of Comet Hale–Bopp we used coma radius 10 000 km and the albedo value 0.05. The τ and T_{mode} parameters were set to fit the spectrum. τ would be 0.0003 for a diluted coma. T_{mode} would be 390 K for subsolar point, 330 K for slowly rotating object and 280 K for fast rotating object.

The measured intensity on 3.6 μm (observations on September 27, 1996; October 7, 1996 (Fig. 6) and December 30, 1997 (Fig. 7)) is very high but note that we measure the scattered solar light at this wave-

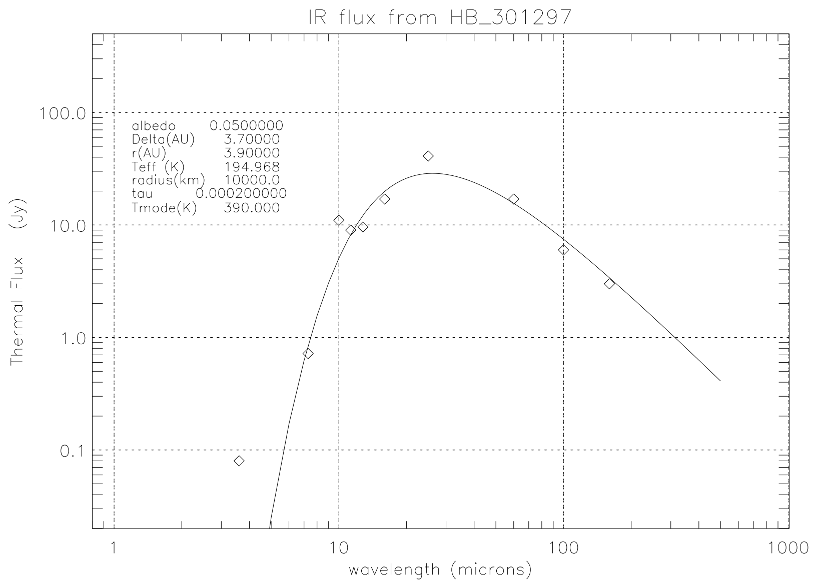

Figure 7: Comet Hale–Bopp, December 30, 1997

length, not only thermal radiation of dust.

In all cases when observations with the 25 μm filter were performed (April 28, 1996; October 7, 1996 (Fig. 6) and December 30, 1997 (Fig. 7)) the measured value was significantly higher than the corresponding point on the fitted Planck curve.

This discrepancy can be explained by other observation — measurement of SWS (Short Wavelength Spectrometer). It dramatically confirmed the olivine identification. Olivine produces the peak around 25 μm that causes the higher value in the observed spectrum of comet Hale–Bopp.

8 Conclusions

We processed meteor spectra observed on the Ondřejov observatory during the period 1990–1994. Elaboration of 44 high quality spectra allow us to analyze statistical dependencies, especially the dependence of spectrum features on the velocity. As mentioned in Section 6, the most important results are:

- Confirmation that the second spectrum is more intensive in case of higher meteoroid velocity
- Low abundance of Na in α Monocerotids which implies a compactness of that material (Štork et al. 1998)
- Specific composition and origin of Geminids
- Detection of CN bands

The analyzing of ISO data continues. ISOPHOT observed also those solid cometary particles which are bigger then dust observed in the visible light.

The absolute photometry of comets observed by ISOPHOT in the range 3–200 μm unambiguously shows that temperature of dust grains depends not only on their albedo and hence on their material, but also on their size. The Planck curves fitted on the observed data can be affected by the presence of silicate bands on 10, 20 and 24–25 μm. If satisfactory fit around maximum of curve (around 10 μm) is found, then the Planck curve represents mainly the temperature of smaller particles.

More informations about the distribution of temperatures, abundance of bigger, millimeter sized particles can probably be obtained by analyzing data from experiments SWS and LWS and by using theory which describe thermal radiation of small particles better than the Planck law. The important result will be the estimation of the abundance and composition of these bigger particles in coma which can be compared with the abundance and composition of particles in the cometary trails (as observed in comet Kopff by ISOPHOT) and in the meteoritic streams as results from radar and TV meteor observations.

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