Radiation of molecules in Benešov bolide spectra

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Introduction

One of the most powerful methods of bolide studies is spectroscopy. The spectra in visible light are dominated by emission lines of metals, most notably Fe, Mg, Na, Ca, Mn, and Cr. By measuring the intensities of atomic lines it is possible to estimate the abundances of various metals in the vapors and thus to approximate the composition of meteoroids. Nevertheless, part of the material can be vaporized in molecular rather than atomic form (in simple molecules like SiO, FeO or AlO). Molecules can be also formed by reactions between meteoric atoms and the air. Abundances derived from atomic lines may therefore not reflect true elemental abundances in the meteoroid.

From these reasons we analyzed molecular radiation in the spectra of the very bright Benešov bolide. The Benešov bolide appeared over the Czech Republic on May 7, 1991 and reached absolute magnitude of –19.5. It was caused by a meteoroid larger than 1 meter. Small meteorites of various mineralogical types were recovered recently [1]. The spectrum of the bolide, recorded on two photographic plates, is probably the richest meteor spectrum ever obtained. It contains hundreds of atomic emission lines, continuous radiation, and molecular bands, and covers the whole bolide trajectory from the altitude of 90 km to 20 km.

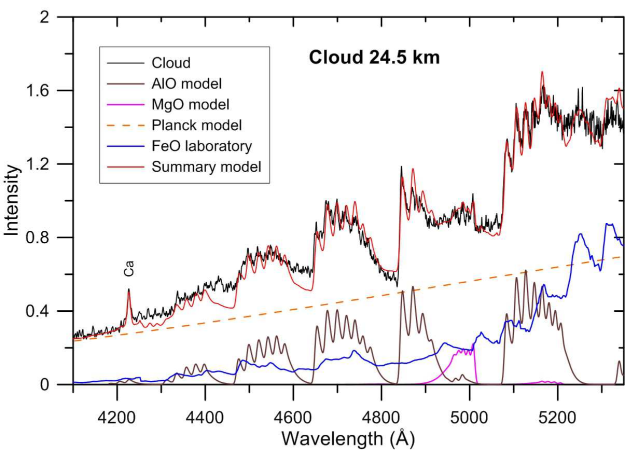

Fig 1 The scan of the cloud at altitudes 24.4-24.6 km (black). Planck blackbody spectrum for temperature 3400 K, laboratory spectra of FeO green and blue systems [3] and modeled spectra of AlO and MgO are given as well. Finally, a summary synthetic spectrum containing all above spectra and a model of atomic line intensities (only Ca having significant intensity) is given in red.

Identifications

The identification of FeO, CaO, AlO, and MgO, reported earlier [2] was confirmed. In addition, the radiation of N_2 was probably detected. The oxides were best seen in the wake and in the radiating cloud left at the position of the bolide flare at the altitude of 24.5 km. The sign of N_2 was seen only in the meteor at lower altitudes. CN and TiO were not found. FeO was present from the beginning of the bolide. We suppose that it was ablated directly in molecular form at high altitudes. CaO was first detected just below 50 km and its intensity relatively to FeO strongly increased toward lower altitudes. Surprisingly, AlO, which is similarly refractive as CaO, followed FeO rather than CaO at lower altitudes. MgO was observed only in the radiating cloud. The spectrum of the cloud is unique because it contains almost no atomic lines.

Interpretation

We compared the data with theoretical calculations of the presence of molecules in the mixture of meteoric vapors and air at various altitudes and temperatures. The equilibrium abundances of 120 chemical species – atoms, molecules, and ions – containing elements O, H, S, N, C, Cl, Si, Al, Mg, Ca, Na, Fe, and Ti were calculated by standard methods of free Gibbs energy minimization [4]. The upper limit of CN is in agreement with theory for ordinary chondrite meteoroid. Most of carbon should be in fact present in the form of CO, but CO bands are too weak to be detected. The non-detection of TiO can be explained by too low temperature in the wake and cloud.

Theoretical spectra of AlO and MgO were computed and compared with observations (Fig. 1). Surprisingly, AlO was found to be about 40 times more abundant than MgO, which we are not able to explain. The rotational temperature of AlO in the cloud (~1000 K) was found to be substantially lower than the vibrational temperature (~3000 K). FeO and CaO could not be analyzed in detail because their molecular constants are not known well enough.

References

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