Emission characteristics of dust in cooling plasma

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Diversity of the local Universe. SAO RAS, October 2019.

The particular feature of a thermal state of dust grains immersed in a hot gas is that they experience temperature fluctuations in a wide range. Temperature distribution function depend of dust grain radius and plasma characteristics. In this work, the temperature distribution function for grains with sizes from 30 A to 3000 A for different gas temperatures and dencities is dicribed along with resulting dust emission spectra.

Temperature distribution function

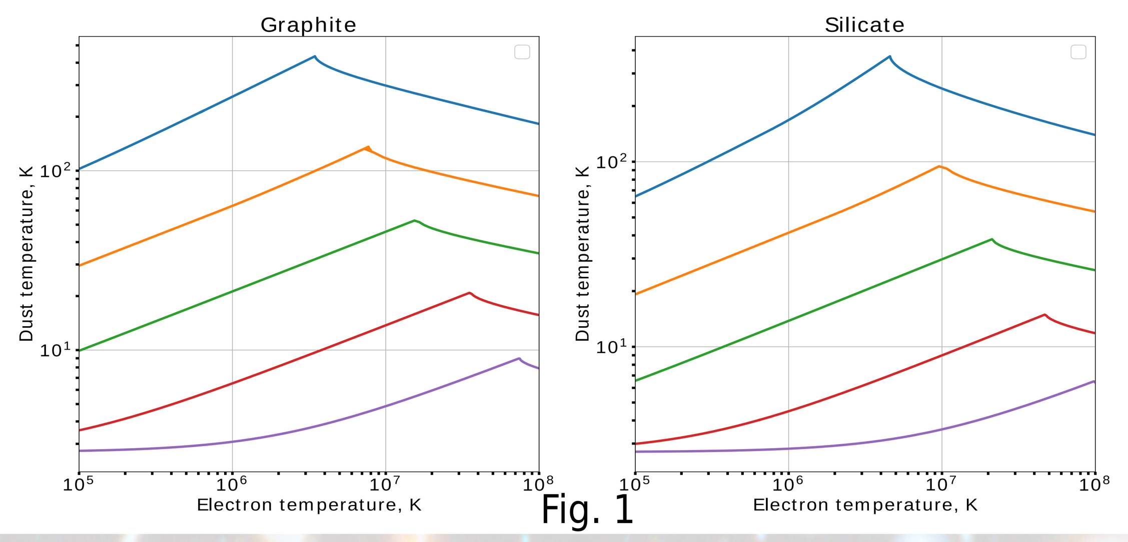

Fig. 1

The Fig. 1 shows the dependence of resulting dust temperature after absorption of the kinetic energy of the incident electron for different types of dust grains.

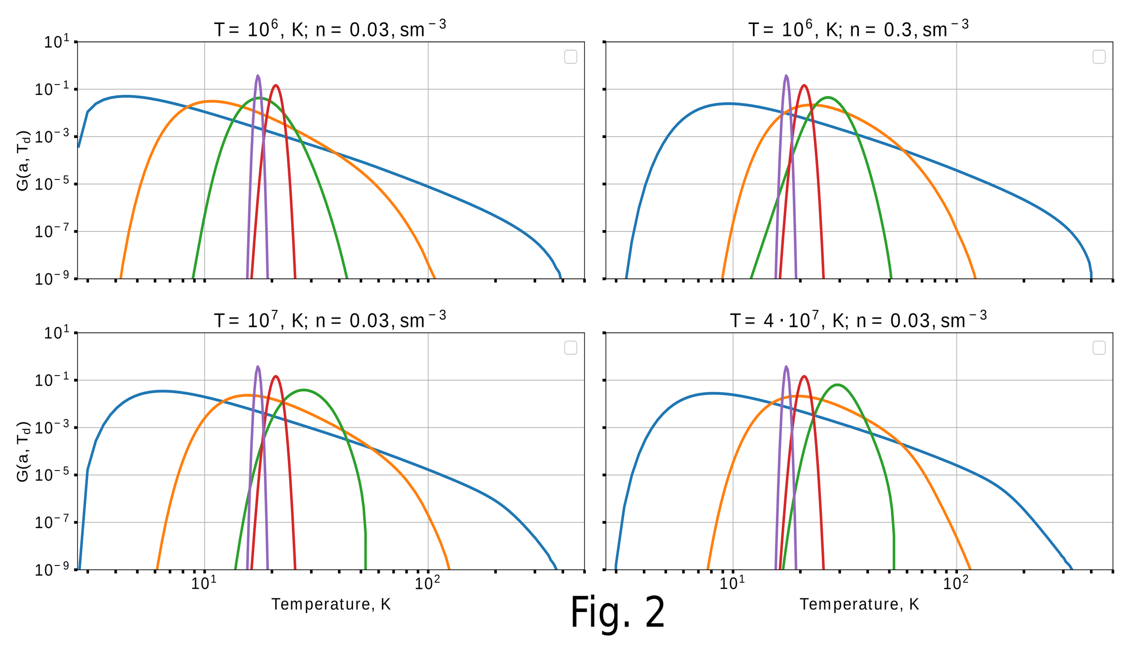

Fig. 2

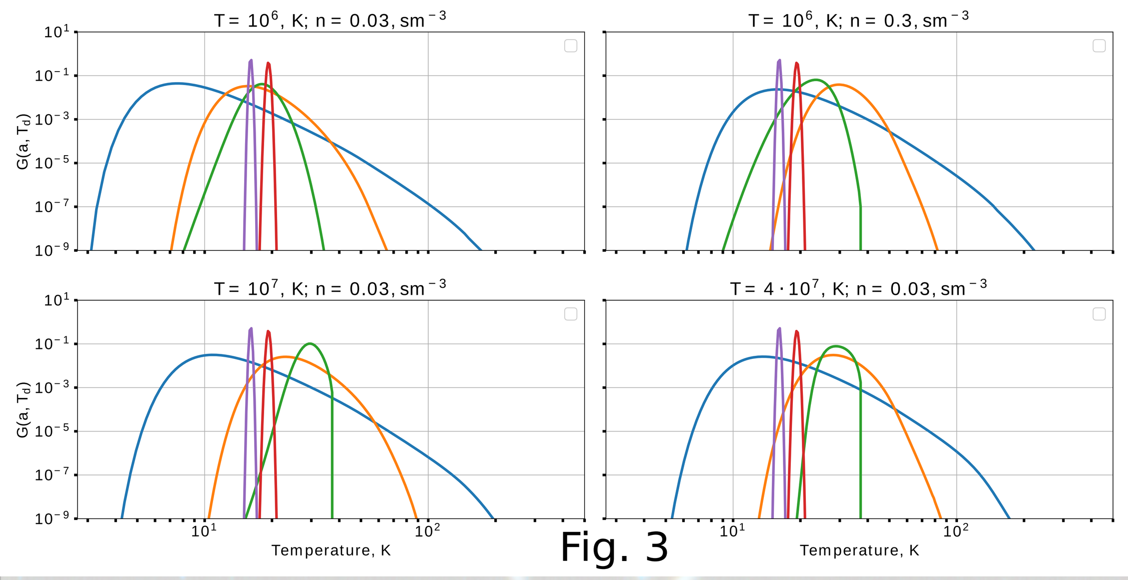

Fig. 3

The Fig.2 for graphite grains and Fig 3 for silicate grains shows temperature distribution functions (TDF) of dust grains surrounded by gas with different characteristics. The curves corresponded to the grains sizes: 30 A, 100 A, 300 A, 1000 A, 3000 A (from widest to narrowest). The wider TDF of graphite under the same dust grains size and ambient gas conditions is explained by difference in the heat capacity and the absorption coefficient dust (2,3).

Function G(a,T) is defined (3) by the expression:

$$G(a, T_d) = \pi a^2 n_e \tau_{coll} \int P_E(a, T_d) f(E) v(E) dE$$

where a - is the grain size, n - is the gas number dencity,
t - is the average time between electronic collisions,
f(E) - is the Boltzmann distribution,
v(E) - is the electrons thermal velocities.

Emission spectra of the dust grains

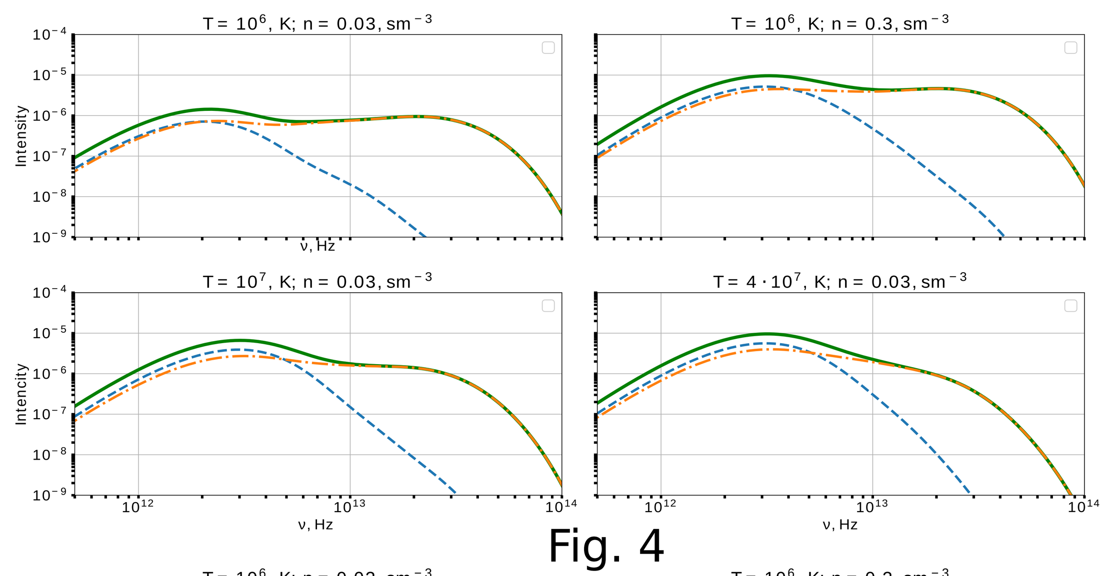

Fig. 4

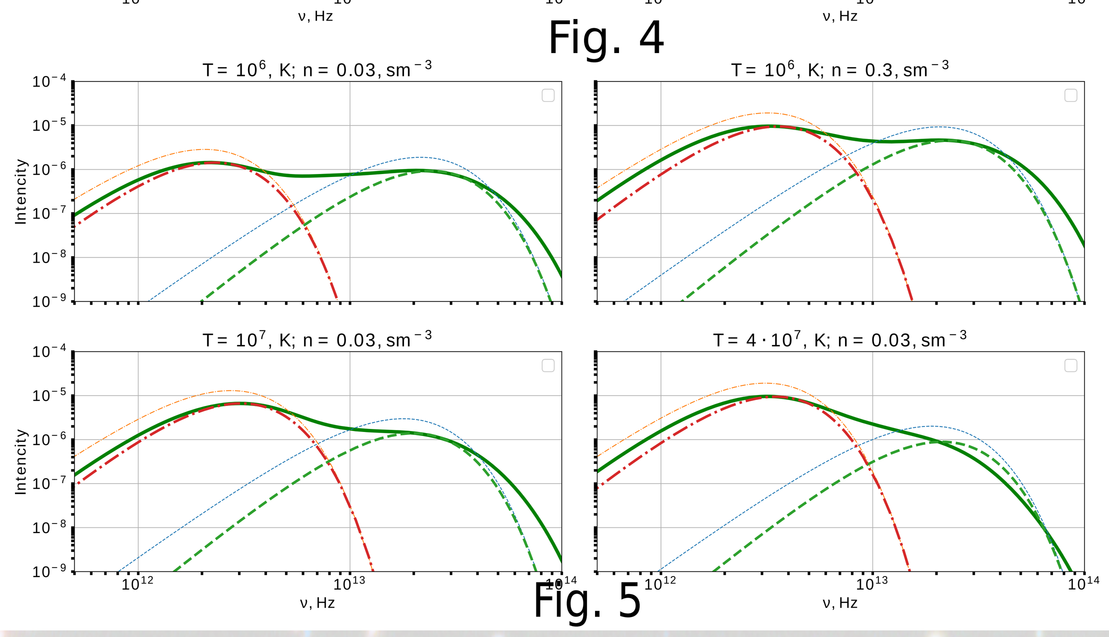

Fig. 5

Fig. 4 - emission spectra of a mixture of dust grains -- thick green solid line, graphite grains -- dash-dotted orange line, silicate - blue dotted line for different gas characteristics.

Fig. 5 - emission spectra of a mixture of dust grains -- thick green solid line, dotted and dash-dotted lines -- two temperature model emissivity of the dust.

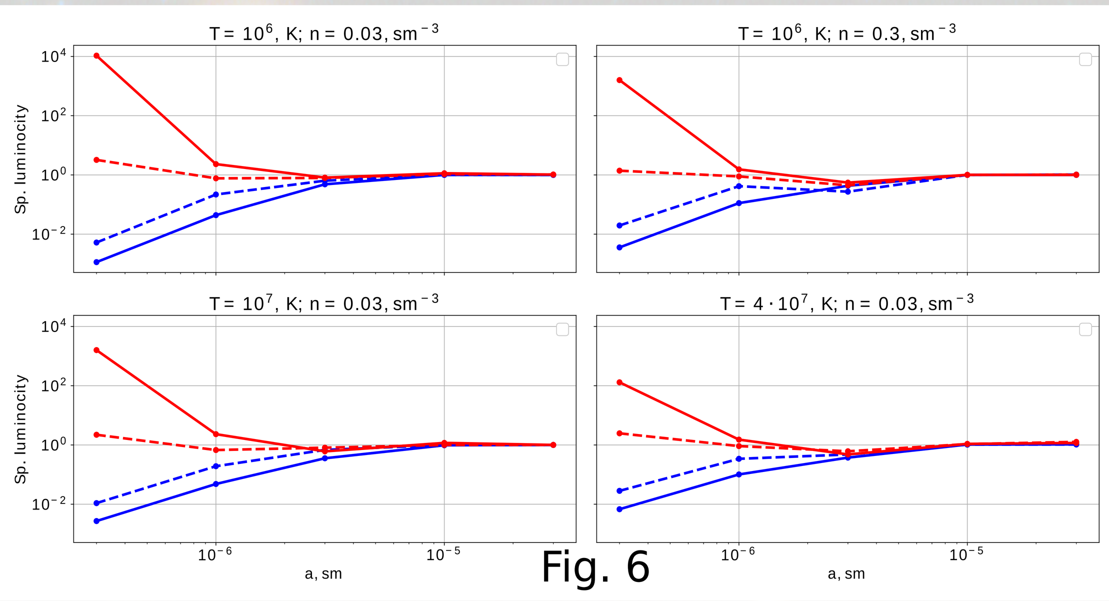

Fig. 6

Fig 6. -- specific luminocity dust depending on the grain sizes. Red solid lines -- luminocity with averaged temperature by modified Planck law.

$$l_{a,s} = \frac{L_{\nu_{p,s}a}}{M_d} \sim \left(\frac{\langle T(a)\rangle_s}{T(a)}\right)^{3+\beta}$$

And dotted lines -- luminocity with averaged temperature by the DTF. Blue color lines -- graphite dust grains and red color lines -- silicate.

$$l_a = \frac{L_{\nu_p a}}{M_d} \sim \left(\frac{\langle T(a)\rangle}{T(a)}\right)^{3+\beta}$$

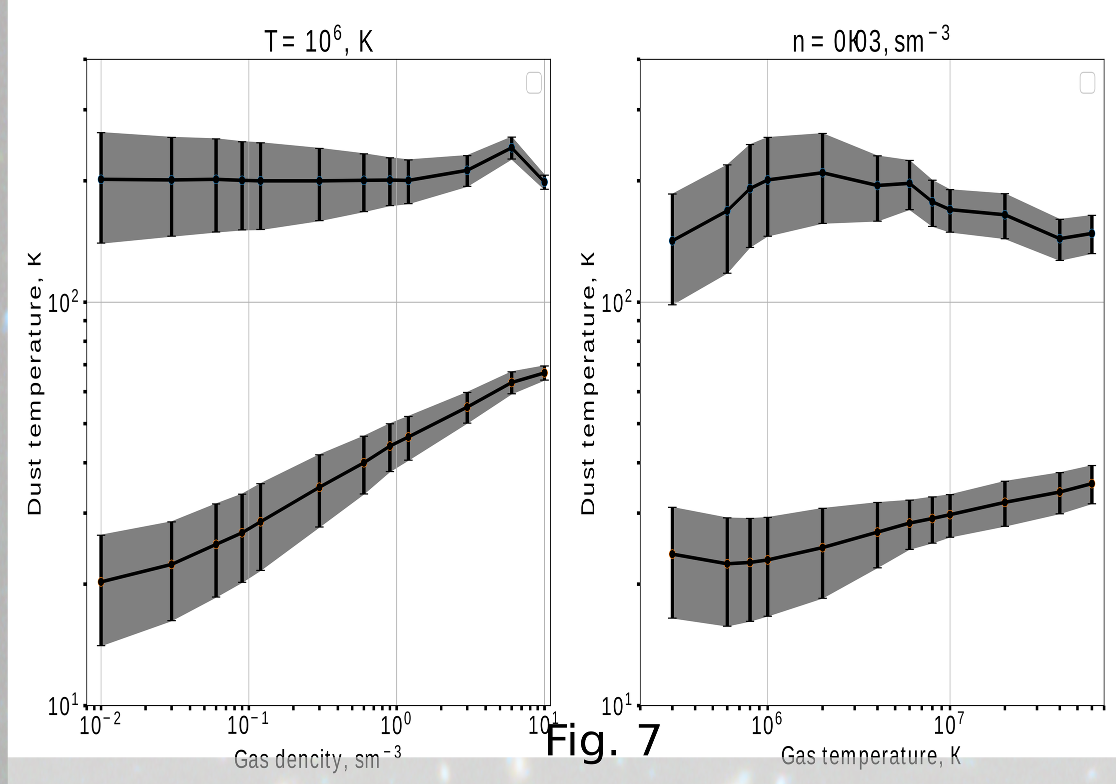

Fig. 7

Fig. 7 -- Temperature cold and hot components in the bimodal emissivity spectra of the dust grains on depending of gas characteristics.

	$T^a = 10^6$; n =0.03	$T = 10^6$; n =0.3	$T = 10^7$; n =0.03	$T = 4 \cdot 10^7$; n =0.03
M_c	4566.26	3357.98	5135.35	3828.24
M_h	0.024	0.144	0.091	0.042

Tab. 1

Mass (in dimensionless unit) coefficients for a different characteristics of ambient medium. Temperature in K and number density in sm^-3.

$$F(\nu) = M_d C \int_{a_{min}}^{a_{max}} a^{-3.5} \int 4\pi a^2 Q(a,\nu) B(\nu, T_d) G(a, T_d) dT_d da$$

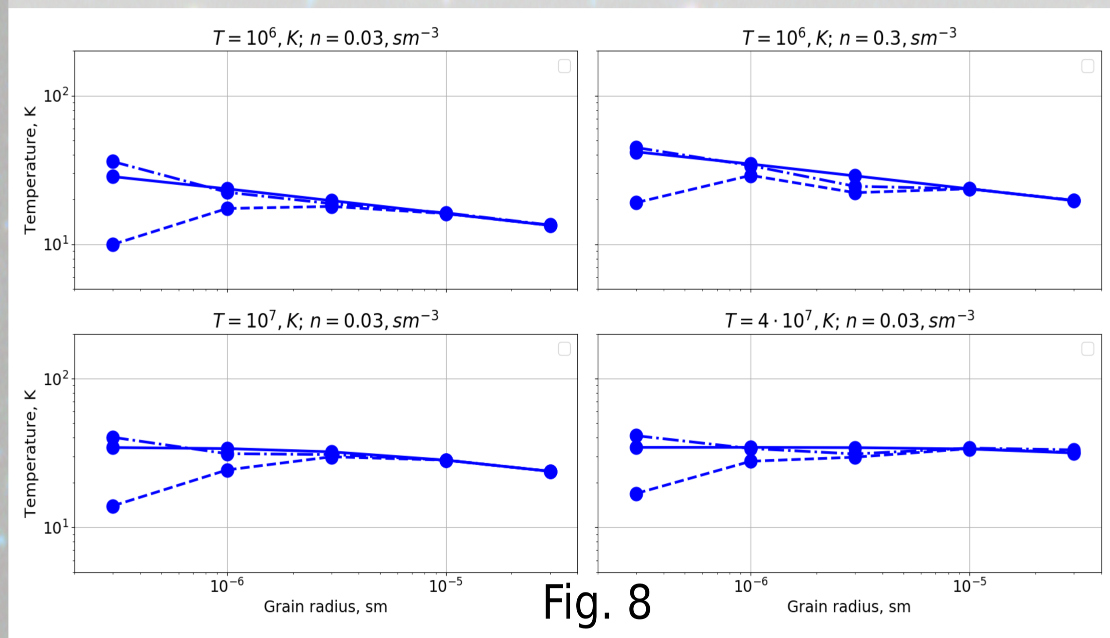

Fig. 8

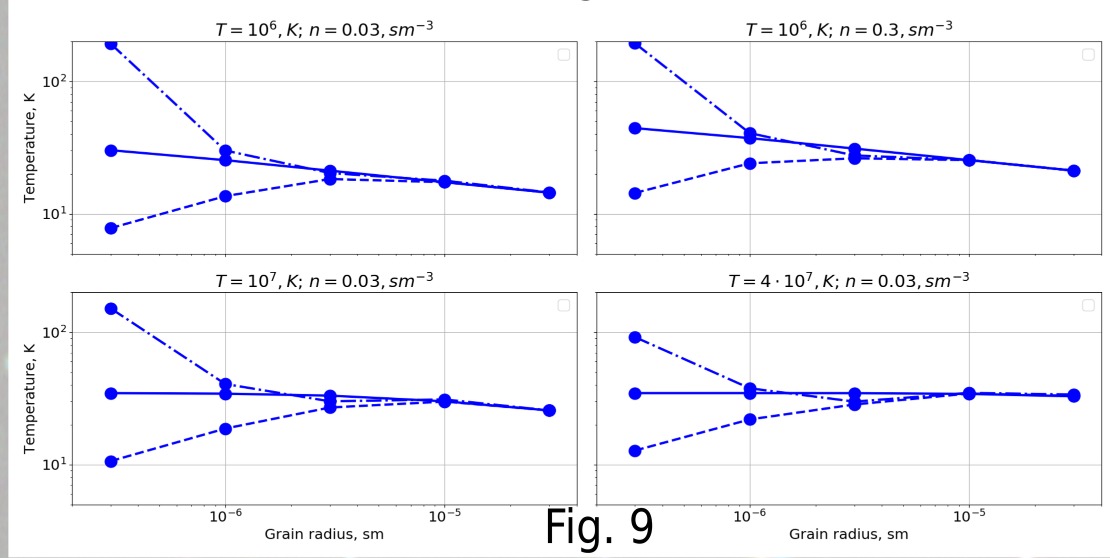

Fig. 9

Fig. 8 -- averaged silicate dust temperatures depending on the grain sizes. Solid line -- equilibrium temperature, dotted line -- averaged for TDF temperature, dash-dotted line -- averaged for emissivity spectra.

Fig. 9 -- averaged graphite dust temperatures depending on the grain sizes. Solid line -- equilibrium temperature, dotted line -- averaged for TDF temperature, dash-dotted line -- averaged for emissivity spectra.

Conclusion

1) The emission spectrum of dust shows a bimodal shape, resembling that of two-temperature spectrum.

2) The main contribution to the high-frequency excess dust emission is made by graphite dust, since it has a greater number of grains with a high temperature.

For more detail see Drozdov S, Shchekinov Y. Astrophysics 2019, (in press).