# ON TWO MECHANISMS OF X-RAY GENERATION IN COMETS

S. Ibadov
Institute of Astrophysics
734670 Dushanbe
USSR

ABSTRACT. The intensity of solar X-radiation scattered by a comet is calculated and compared to the proper X-radiation of the comet due to impacts of cometary and interplanetary dust particles. Detection of X-radiation of dusty comets at small heliocentric distances ($R \leq 1$ a.u.) is found to be an indicator of high-temperature plasma generation as result of grain collisions.

## 1. Introduction

The study of comets has been carried out at present in ultraviolet, optical, infrared and radio ranges (e. g. see /1-2/). Meanwhile the investigation of the cometary dust component interaction with the dusty matter of interplanetary medium reveals the possibility of arising the measureable proper X-ray emission of comets due to production of high-temperature plasma balls at heliocentric distances $R \leq 1$ a.u. /3/. X-radiation from comets may also appear in the way traditional for cold astronomical objects, namely due to scattering of solar X-rays by cometary matter.

## 2. Scattering of Solar X-Radiation by Comets

The intensity of cometary emission excited by incident radiation of the Sun may be presented as

$$I_s = \frac{I_o}{4R^2 r^2}(4A_1 s_1^2 f_1 + A_2 r_h^2 f_2). \qquad (1)$$

Here the first term in the right hand part corresponds to radiation of the optically thick zone of the cometary head



R. H. Giese and P. Lamy (eds.), Properties and Interactions of Interplanetary Dust, 365–368.

($\tau \geq 1$) and the second term - to the optically thin one ($\tau < 1$); $I_0$ is the intensity of solar X-radiation at the Earth's distance; R is the comet - detector distance; $A_1$ is the albedo of the part of cometary head having the "optical thickness" $\tau = 1$; $s_1 = \pi \sigma n_n r_n$ is the "sight distance" for solar rays passing across the cometary head with $\tau = 1$; $f_1$ is the phase function of the optically thick part of the cometary head; $A_2 = (4/3) a \bar{n} \sigma r_h$ and $f_2$ are the albedo and phase function of the optically thin part of the head; $r_h$ is the radius of the head; $a \leq 1$ is the factor of absorption: $a = 1$ at zero absorption; $\sigma$ is the cross-section of extinction for incident photons; $\bar{n}$ is the mean number density of scattering particles in the optically thin part of the head; $n_n \equiv n\ (r_n, R)$ is the number density of atomic particles near the surface of the nucleus with the radius $r_n$. This formula may be used for calculation both the spectral and, after corresponding integration over the spectrum, the integral intensity of radiation.

According to (1) for bright comets of Mrkos 1957V type with realistic values of $I_0(h\nu \geq 100$ eV, R= 1 a.u.)= 0,1 erg cm$^{-2}$ s$^{-1}$ /4/, $n(r_n$, R= 1 a.u.)= $10^{14}$ cm$^{-3}$, $r_n = 3 \cdot 10^6$ cm, $r_h = 10^{10}$ cm, $\bar{n} = 2{,}7 \cdot 10^7$ cm$^{-3}$ /1/, $\sigma(h\nu \geq 100$ eV) = $10^{-19}$ cm$^2$, $a = A_1 = 10^{-4}$ /5/, $f_1 = f_2 = 1$ we have $I_s(h\nu \geq$ 100 eV, R= 1 a.u., r= $1{,}5 \cdot 10^{13}$ cm)= $7 \cdot 10^{-15}$ erg cm$^{-2}$ s$^{-1}$ : both terms of (1) give almost equal contribution to $I_s$. The value of $I_s$ obtained is approximately one order of magnitude lower than the sensitivity threshold of modern X-ray telescopes (e.g. see /6/). Hence, comets are invisible in solar X-rays at heliocentric distances R $\gtrsim$ 1 a.u.

## 3. New Component of Cometary Emission

At small heliocentric distances (R $\lesssim$ 1 a.u.) the generation of proper X-radiation of comets due to interaction of cometary and interplanetary dusty matter is also possible together with the solar X-rays scattering. The intensity of this radiation $I_x$ and the energy of quanta, corresponding to spectral distribution maximum, $h\nu_m \equiv \mathcal{E}_m$, we may present according to /3/ as

$$I_x(\mathcal{E} \geq \mathcal{E}_m, R, r) = I_{x1}(r_x/r)^2 R^{-(p + 3/2)}, \quad (2)$$

$$\mathcal{E}_m = \mathcal{E}_{m1} R^{-1}, \quad (3)$$

where $I_{x1} = 1{,}7 \cdot 10^{-4}$ erg cm$^{-2}$ s$^{-1}$ is the intensity of proper radiation of a comet at R= 1a.u. and r= $r_x$ :

$$r_x = \pi n_d(r_n, R) \sigma_{dd} r_n^2 \quad (4)$$

is the radius of the X-ray active zone of the cometary head, where the interplanetary dust particles penetrating into the coma transform into plasma balls due to impacts with cometary grains; $n_d(r_n, R)$ is the number density of cometary dust particles near the cometary surface; $\sigma_{dd}$ is the cross-section for collisions of cometary and interplanetary grains; p=1,5 is the parameter of spatial distribution of mass density of interplanetary dust matter; $\varepsilon_{m1} \equiv \varepsilon_m(1)$= 65 eV is the most probable energy of quanta emitted by plasma balls at R=1 a.u.

## 4. Comparison of Two X-Ray Generation Mechanisms

The integral intensity of solar X-radiation may be written as

$$I_0(\varepsilon \geq \varepsilon_1) = \frac{I_0^*}{(\gamma - 1)\varepsilon_1^{\gamma-1}} . \tag{5}$$

Here $I_0^* = 10^3$ is the parameter of the solar differential energy spectrum; $2 \leq \gamma \leq 4$ is the spectral index; the numerical values correspond to energy range of solar photons $10^2 \leq \varepsilon \leq 10^3$ eV at quiet conditions according to /4/.

For registration of the proper radiation of comets the choice of passing threshold of counter as $\varepsilon_1 = \varepsilon_m$ seems most natural. In this case taking into account (3) and (5) under conditions of equal contributions of both right hand terms of (1) we get its integral presentation as

$$I_s(\varepsilon \geq \varepsilon_m, R, r) = \frac{2I_0^* A_1 f_1}{(\gamma - 1)\varepsilon_{m1}^{\gamma-1} R^{3-\gamma}} \left(\frac{s_1}{r}\right)^2 . \tag{6}$$

Here $A_1$ and $s_1$ represent the integral values of these parameters in the energy range considered.

From (6) follows that $I_s$ weakly changes with R at $\gamma \geq 2$ while $I_x$ by (2) quickly increases with decreasing R. On the basis of (2), (4) and (6) we may find the interval of heliocentric distances where the intensity of proper radiation of comets exceeds the intensity of scattered radiation, namely

$$R < \left\{ \frac{I_{x1}(\gamma - 1)\varepsilon_{m1}^{\gamma-1}}{2I_0^* A_1 f_1} \left[\frac{n_d(r_n, R)\sigma_{dd}}{n(r_n, R)\sigma}\right]^2 \right\}^{1/(p+\gamma-3/2)} . \tag{7}$$

https://doi.org/10.1017/S025292110008492X Published online by Cambridge University Press

Inserting into (7) realistic values of $\gamma=3, n_d(r_n, R) = 10^4$ cm$^{-3}$, $\sigma_{dd}=5\cdot10^{-9}$ cm$^2$ and numerical values of other parameters mentioned we have $R < 3$ a.u. At the same time the initial temperature of plasma balls in the generation zone of proper X-radiation of comets according to /3/ will be $T_0(R \leq 1$ a.u.$) \geq 3\cdot10^5$ K.

Thus the registration of X-radiation of dusty comets at small heliocentric distances ($R \leq 1$ a.u.) in the definite energy range ($\mathcal{E} \geq \mathcal{E}_m$) and at quiet Sun may be an indicator of high-temperature plasma generation as a result of grain collisions, i.e. of the physical process not realized yet under terrestrial laboratory conditions.

## 5. Acknowledgements

The author is grateful to Prof. O.V. Dobrovolsky, Drs Yu.N. Gnedin, B.Yu. Levin, I.M. Podgorny, R.A. Sunyaev and L.M. Shul'man for stimulating discussions.

## References

1. Dobrovolsky, O.V.: 1966, Comets, Nauka, Moscow.

2. Wilkening, L.L. (ed.): 1982, Comets, Proc. IAU Colloq. No. 61, Arizona Univ. Press, Tucson.

3. Ibadov, S.: 1983, in T.I. Gombosi (ed.), Cometary Exploration, Proc. Intern. Conf., Budapest, Hungary, vol. 1, p. 227.

4. Hinteregger, H.E.: 1965, Space Sci. Rev. 4, 461.

5. Blokhin, M.A.: 1957, Physics of X-rays, GITTL, Moscow.

6. Trümper, J.: 1980, The Röntgen Satellite (ROSAT), Preprint Max-Plank Institute für Physik und Astrophysik, München, FRG.

7. Grün, E.: 1980, in V.A. Dergachev and G.E. Kocharov (eds.), Cosmic Rays, Proc. V11 European Cosmic Ray Symposium, Leningrad, USSR, p. 172.