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Prediction of CO Cameron band and atomic oxygen visible emissions in comets C/2013 A1 (Siding Spring) and 67P/Churyumov–Gerasimenko

Susarla Raghuram and Anil Bhardwaj
Space Physics Laboratory, Vikram Sarabhai Space Centre, Thiruvananthapuram, Kerala, 695022 India.
(raghuramsusarla@gmail.com / Fax: +91 471 2706535)

Abstract

The forbidden emissions of cometary species have special importance in the cometary spectra. The excited species which produce these forbidden emissions can not be populated by direct solar radiation excitation. These metastable species are produced mainly from dissociative excitation and ion-electron recombination reactions. Thus the observed emissions have been used as tracers of parent cometary species. The CO ($a^3\pi$ –$X^1\Sigma$) is a forbidden transition which produces Cameron band emission in the ultraviolet region during dissociative excitation of CO-bearing neutrals and the dissociative recombination of CO-ionic species in the cometary coma. Similarly, the forbidden transitions of metastable atomic oxygen ^{1}S-^{3}P (green, 5577 Å), and ^{1}D-^{3}P (red-doublet, 6300 and 6364 Å) produce line emissions in the visible region. These emissions have been used to probe H_2O and CO_2 abundances in the comets. We have developed a coupled chemistry-emission model to study various production and loss mechanisms of these excited metastable states. The model is applied to comet C/2013 A1 (Siding Spring) which will have a close fly-by of Mars during mid October, 2014, when Indian Mars orbiter Mission and NASA's Maven, would be orbiting the planet. The model is also applied on ESA's Rosetta mission target comet 67P/Churyumov–Gerasimenko which will be useful for different observations over various heliocentric distances. The predicted intensities and quantitative analysis of these emissions can be a theoretical support for various space and ground-based observations.

1. Introduction

Although comets are water dominated bodies it is difficult to observe H_2O directly in the coma by making ultraviolet and visible observations. The emissions from H_2O dissociative products, like, OH 3080 Å and atomic oxygen visible (5577, 6300, 6364 Å) lines have been used in quantifying the water production rate in comets [1, 2, 3, 4, 5]. The estimation of CO_2 abundance in comets has been done using emissions of its dissociative products like CO Cameron band and atomic oxygen emission lines [6, 7, 8, 9, 10]. Since the excited species are getting produced via different production mechanisms a quantitative analysis of these production processes is essential to estimate their parent species abundances.

2. Model

We developed a coupled chemistry-emission model which account for many photochemical reactions that govern the number densities of CO($a^3\pi$), O(^{1}S), and O(^{1}D) in the cometary coma [11, 12, 13]. Major production and loss reactions of these excited states are incorporated in the model. The calculations have been done on comets C/2013 A1 (Siding Spring) and 67P/Churyumov–Gerasimenko. In the model we assumed the water production rates on comets 67P/Churyumov–Gerasimenko and C/2013 A1 (Siding Spring) as 5×10^{27} s^{-1} at $r = 1.0$ au and 5×10^{28} s^{-1} at $r = 1.5$ au, respectively, for 3% CO_2 and 7% CO relative abundances. We also did model calculations for different H_2O production rates and various CO_2 and CO relative abundances.

3. Results

The gas production rates on these comets differs by an order of magnitude. The model calculated green to red-doublet emission intensity ratio on these comets are plotted in Figure 1. Due to high gas production rate and also because of strong collisional quenching of O(^{1}S) and O(^{1}D) the calculated G/R ratio on comet C/2013 A1 differs with that of 67P. The modelled CO

Cameron band emission intensity profiles as a function of projected distance on both these comets are shown in Figure 2. For the assumed gas production rates and relative CO_2 and CO abundances we found that the Cameron band intensity profile as a function of projected distance on these comets is nearly same. Though the gas production rate on comet C/2013 A1 is higher due to large heliocentric distance the estimated CO Cameron band emission is neary same as on comet 67P.

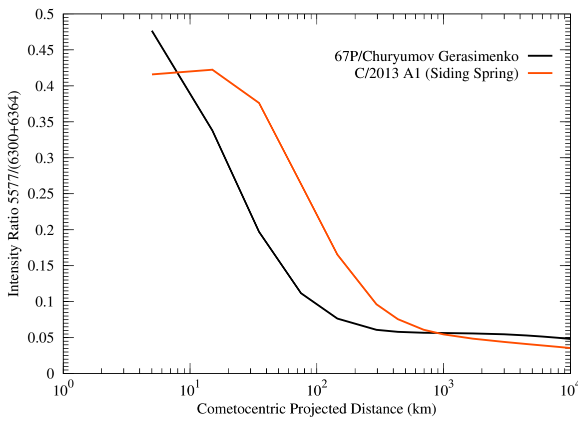

Figure 1: The model calculated green to red-doublet emission intensity ratio on comets C/2013 A1 (Siding Spring) (at $r = 1.5$ au) and 67P/Churyumov–Gerasimenko (at $r = 1.0$ AU).

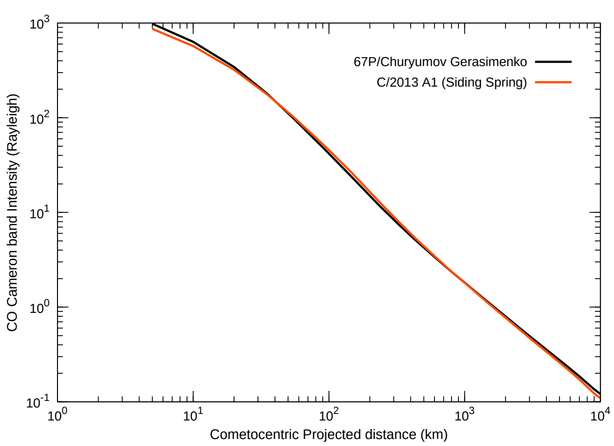

Figure 2: The model calculated CO Cameron band emission intensity profiles on comets C/2013 A1 (Siding Spring) (at $r = 1.5$ au) and 67P/Churyumov–Gerasimenko (at $r = 1.0$ AU).

4. Summary and Conclusions

By incorporating various photon, photoelectron, and dissociative recombination reactions in the model, we calculated the production and loss rates of $CO(a^3\pi)$, $O(^1S)$, and $O(^1D)$ in the cometary comae of comets C/2013 A1 (Siding Spring) and 67P/Churyumov–Gerasimenko. The modelled $CO(a^3\pi)$, $O(^1S)$, and $O(^1D)$ density profiles are used to predict CO-Cameron band emission and atomic oxygen visible emission as a function of projected distance on these comets.

References

[1] Delsemme, A.H., Combi, M.R., Astrophys. J. 228, 330–337, 1979.

[2] Festou, M.C., Feldman, P.D., Astron. & Astrophys. Vol. 103, 154–159, 1981.

[3] Fink, U., Johnson, J.R., Astron. J. Vol. 89 (10), 1565–1572, 1984.

[4] Morgenthaler, J.P. et al., Astrophys. J., Vol. 563, 451–461, 2001.

[5] Schultz, D., Li, G.S.H., Scherb, F., Roesler, F.L., Icarus, Vol. 96 (2), 190–197, 1992.

[6] Feldman, P.D., Festou, M.C., Tozzi, G.P., Feldman, P.D., Weaver, H.A., Astrophys. J., Vol. 475, 829–834, 1997.

[7] Weaver, H.A., Feldman, P.D., McPhate, J.B., A'Hearn, M.F., Arpigny, C., Smith, T.E., Astrophys. J., Vol. 422, 374–380, 1994.

[8] Furusho, R., Kawakitab, H., Fusec, T., & Watanabe, J. 2006, Adv. Space Res., 9, 1983.

[9] McKay, A. J., Chanover, N. J., Morgenthaler, J. P., et al. 2012, Icarus, 277

[10] Decock, A., Jehin, E., Hutsemékers, D., & Manfroid, J. 2013, Astron. & Astrophys, 555, A34.

[11] Bhardwaj, A. and Raghuram, S., Astrophys. J., Vol. 748, pages 13, 2012.

[12] Raghuram, S. and Bhardwaj, A., Planet. Space Sci., 139–149, 2012.

[13] Bhardwaj, A. and Raghuram, S., Mon. Not. R. Astron. Soc., Vol. 412, pages L25-L29, 2011.