Modeling the neutral sodium tails of comets

K. Birkett[1,2], G. Jones[1,2], and A. Coates[1,2]

[1]Mullard Space Science Laboratory, University College London
[2]The Centre for Planetary Sciences at University College London/Birkbeck

Neutral sodium is typically easy to detect in active comets around perihelion, due to the very high efficiency of the sodium D transition, and, at some comets, a distinct neutral sodium tail is observed.

The first distinct neutral sodium tail images were apparent in C/1995 O1 (Hale-Bopp) data taken using CoCam [1], but, since this initial detection, similar features have been observed at near-Sun comets using the LASCO coronagraph on SOHO. A full picture of the distribution and evolution of neutral cometary sodium may best be established using a combination of spectra and images in different filters at multiple times throughout the orbit.

The high efficiency of the sodium D transition has allowed it to be detected in systems, even if the column density of sodium is extremely low. In these instances it is sometimes possible to determine some of the system's characteristics from the sodium emission detection, such as in Io's plasma torus [2] and Enceladus's plume [3,4]. It is hoped that a similar approach may be applied to the active cometary environment, but, at present, the production of neutral sodium is unknown. Various authors [5–9, thorough review presented in 10] have suggested various combinations of sources of neutral sodium in the nuclear region, near-nuclear region, dust tail, and ion tail.

The morphology and evolution of the neutral cometary sodium tail are difficult to intuitively predict due to the Swings and Greenstein effects. In order to understand the wide variety of cometary observations of neutral sodium available we have developed the first fully three-dimensional, heliocentric-distance-dependent, versatile Monte Carlo neutral sodium tail model, which incorporates the unintuitive variation in radiation pressure influences on sodium atoms with different heliocentric velocities. Our model was initially based on that of Brown et al [7].

We present preliminary results from this model. We have found initial agreement with the overall morphology and brightness of the neutral sodium tail observed at C/1995 O1 (Hale-Bopp, for which this phenomenon was studied most extensively) and our model, and have begun to extend the study to other comets of interest. We also present our initial analysis of the likely presence of neutral sodium in the SOHO LASCO images of C/2012 S1 (ISON) and a comparison of this dataset with our model. The versatility of the model allows it to be easily adapted to any other cometary sodium tail.

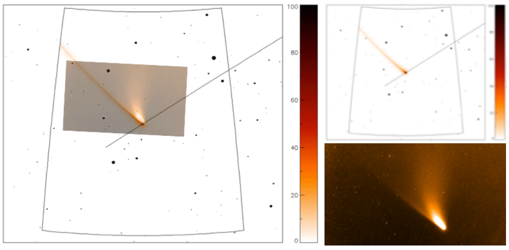

Figure: Left: Model-data overlay produced by matching star fields show good agreement with overall sodium tail morphology for comet C/1995 O1 (Hale-Bopp). Top right: Simulation result for comet Hale-Bopp at 21:00 UT on 1997 April 16 using a collision radius of 40,000 km. Bottom right: CoCam images of comet Hale-Bopp taken using sodium filter at 21:08 UT on 1997 April 16.

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