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Modelling Cometary Sodium Tails

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Abstract

Neutral sodium is readily observed in cometary spectra and can be seen to form its own distinct tail around high activity comets. We present a brief overview of neutral sodium tail observations to date and discuss the importance of theoretical modelling in understanding these data. We have developed a new, 3D Monte-Carlo model of cometary sodium that incorporates several advancements over previous models. It includes weightings due to solar flux variation with heliocentric distance, and comprehensive handling of the Swings and Greenstein effects on the neutral sodium tail, which can have particularly dramatic effects in near-Sun comets. Some preliminary results from this model are presented, including predictions of the structure of the eagerly anticipated neutral sodium tail at Comet C/2012 S1 (ISON).

1. Introduction

Neutral atoms form distinct tails around high activity comets. Solar radiation pressure causes a force on the sodium atoms at the comet. As strong sodium absorption lines are present in the solar spectrum, the magnitude of this force is dependent upon the Doppler shift of the incident solar radiation. Therefore the heliocentric velocity of the sodium atom directly determines its acceleration. This produces unique effects, such as a stagnation region on the sunward side of the nucleus.

2. Model

Our model was initially based on the Monte-Carlo model of Brown et al [1], which considered the evolution of sodium atoms produced at a fixed nucleus based purely on their heliocentric velocity. The evolution close to the nucleus was parametrised as radially outwards inside a given 'collision radius', which requires further investigation.

We have significantly expanded this model to a full 3D simulation that includes the effects of a varying heliocentric distance due the comet's orbital motion using JPL's Horizons database [5] and various brightness effects. Our sodium tail model now sucessfully incorporates the neutral sodium lifetime, variation of cometary sodium emission due to Fraunhofer absorption lines and solar flux variation with heliocentric distance. Therefore, the sometimes significant Swings and Greenstein effects on the sodium population are considered comprehensively.

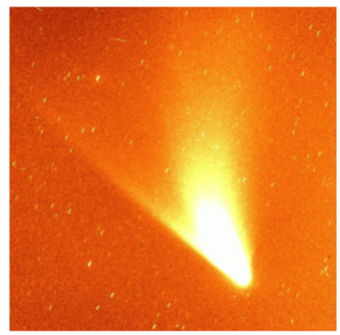

Figure 1: Sodium tail of Comet C/1995 O1 (Hale-Bopp) [2]. Although sodium tails had been detected previously, e.g. Nguyen-Huu-Doan (1960) [4], observations of Hale-Bopp revealed the morphology and dynamics of the neutral tails (Cremonese et al. 1997) [2].

3. Summary and Conclusions

Sodium is relatively easy to detect and so can potentially be used to trace mechanisms in the coma that are otherwise difficult to observe [3]. However, the source of neutral sodium in the tail currently remains unknown. We have made a sucessful start in producing a fully heliocentric, distance dependent neutral sodium tail model that will facilitate testing of different sodium production functions. By comparison with experimental observations we will begin to understand the underlying mechanisms.

References

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