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Realistic Detectability of Close Interstellar Comets

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Abstract

From our understanding of planet formation we know that many comets are created and ejected, but we have yet to observe "interstellar" comets from other stars. A detailed estimation of the population of these comets has been recently determined [2]. Those results concluded that based on their size and distribution that the LSST would be unlikely to see any interstellar comets beyond 5 AU. Our work takes into account the gravitational focusing of the Sun and the brightening of comets as they come closer to the Sun. We will more accurately describe the probability of realistically observing these close interstellar comets. Using numerical simulations we track the comets in their hyperbolic orbits about the Sun. We show that the velocity of the Sun relative to the galactic Local Standard of Rest has negligible effect on the probability of observation, while the velocity dispersion of the comets has a greater effect though still small compared to uncertainties in the population. We will present the magnitude distribution of comets, including a model for comet brightening or outgassing, and discuss the prospects for LSST in detecting an interstellar comet.

1. Introduction

To determine the realist detectability of interstellar comets we simulate the population of the comets and their behavior. The population we use is based on the work from Moro-Martin [2]. The number of comets, their size and mass are determined by using a consistent density for each of the comets, a total mass density, and a broken power law distribution for their sizes. Using this population of comets we simulate the hyperbolic orbits of the comets about the Sun and their behavior as they approach the Sun. We then determine the maximum magnitude of the comets during their orbits as observed from the Earth. The probability of observation is determined from the magnitudes of the individual comets. We will discuss in particular the probability of observation from the view point of the LSST.

2. The LSST

The Large Synoptic Survey Telescope(LSST) will be able to cover large areas of the night sky at a faster rate and better magnitude than currently possible. As a result the LSST is the perfect candidate for discovering interstellar comets. The LSST will be producing large amounts of survey data and it will be hard to find these comets if we are not looking for them. Our research will provide a realistic discussion of how many comets we expect to see and at what rate, so that we can dedicate a proportionate amount of resources to finding them. We will also discuss the specific duration windows that the comets will be above a magnitude detection limit and within the Universal Cadence fields to be surveyed by the LSST.

3. Important Factors

The initial condition of the comets and their behavior as the approach the Sun can have significant effect on their apparent magnitude. To better understand these effects and to ensure more accurate results we characterize how each of the different behaviors effect the magnitude of the comets. We characterize the initial velocities, the velocity of the Sun relative to the galactic Local Standard of Rest, and the effects of comet brightening or outgassing.

3.1. Initial Comet Velocity

The initial velocities of comets has a small but not insignificant effect on the distribution of magnitudes observed. For the simulation we chose an intial random 3-dimensional velocity of fixed length for the comets, we will call it v_initial. By definition v_initial is a velocity relative to the galactic Local Standard of Rest, i.e., the average motion of nearby stars in the galaxy. We can determine the importance of v_initial by comparing the frequency of comets that come within 10 AU of the sun-Earth distance (the minimum value of

$(d\_s^2 * d\_e^2)^{1/4}$ where d_s is the distance to the Sun and d_e is the distance to the Earth from the comet). Figure 1 shows that about twice as many comets that have a v_initial of 5 km/s come closer than comets that have a 30 km/s v_initial. Since this factor is significant we will use a range of velocities around what is thought to be the most realistic, thus ensuring a comprehensive study.

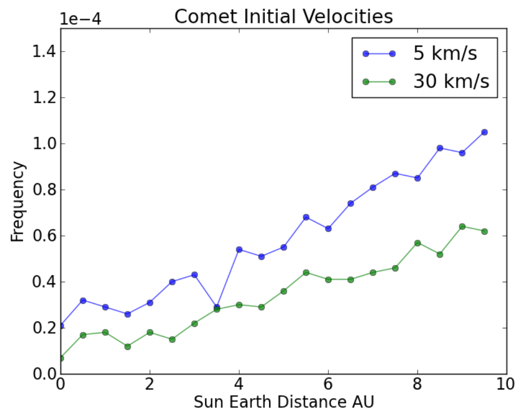

Figure 1: The initial velocity of the comets has a significant effect of the frequency of comets that come close to the Sun and the Earth.

3.2. Sun Velocity

The velocity of the Sun relative to the Local Standard of Rest has no significant effect on the frequency of close comets. We simulated the Sun at three different velocities relative to the Local Standard of Rest(LSR). We used the Dehnen & Binney 1998 (db98) velocity of (11.1, 5.25, 7.25) km/s [1]. Secondly, we used the more recent Schönrich, Dehnen & Binney (sbd10) velocity of (11.1, 12.24, 7.25) km/s [3], and finally we used a static velocity where the Sun was at rest relative to the LSR. Figure 2 shows that there is no significant difference in the frequency of close comets for the different Sun LSR velocities. Since there is no difference we will use the newest sbd10 velocity for our simulations, but there may be a significant difference in the distribution of the comets in the sky, so we will not completely ignore the Sun's velocity.

3.3. Comet Brightening

As comets approach the Sun they have been observed to suddenly increase in brightness by up to 10 magnitudes. This behavior alone could dramatically increase

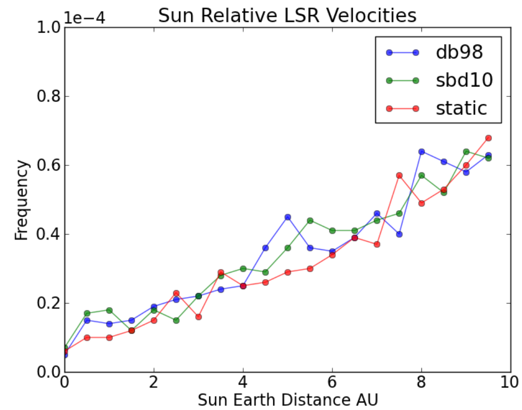

Figure 2: The velocity of the Sun has a little effect of the frequency of comets that come close to the Sun and the Earth.

the probability of observation. Because little is known about this behavior and the focus of this research is not on developing a model on this behavior, we will use basic models and again characterize how each model effects the probability of observation.

4. Summary

Combining all of these factors with their relative importance we will have a comprehensive model to discuss the realistic detectability of interstellar comets from the LSST. We will present our estimates as to how many and how often the LSST will be able to observe such comets. We will also present how each of the factors contributed to the probability of observation so that as we do learn more about the particular behavior of these comets we can better predict how our learnings will affect the probability of observation.

References

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