

Detecting Dark Matter Mini-Halos Via Interactions with Binary Star Systems

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ABSTRACT

Dark matter clumps can provide an avenue for indirectly detecting dark matter. Dark matter mini-halos, or clumps, are earth-mass to solar-mass overdensities of dark matter. There are over 5×10^{15} of these clumps in our galaxy. By looking at interactions of these dark matter clumps with binary star systems in the Milky Way, it may be possible to detect dark matter. Binary star systems are capable of capturing dark matter clumps. When dark matter is captured, there could be an increase in the number of gamma rays observed from a binary system, or an increase in the total luminosity in the stars of the binary system. The results of this project show that there is approximately one capture event in the Milky Way every 500 years. This corresponds to roughly 20 million total capture events in the history of the galaxy. In individual binary systems there could be as much as 10^{25} kg, or 10 earth masses of dark matter captured by one binary system. The capture of this much dark matter in one system could be enough to be detectable, either by looking at gamma ray emission from binaries or by looking at binary star luminosities and temperatures.

INTRODUCTION

- Dark matter comes in earth mass to solar mass clumps that formed very early in the universe
- These clumps should still exist today
- We are trying to find a method to detect these clumps in our galaxy

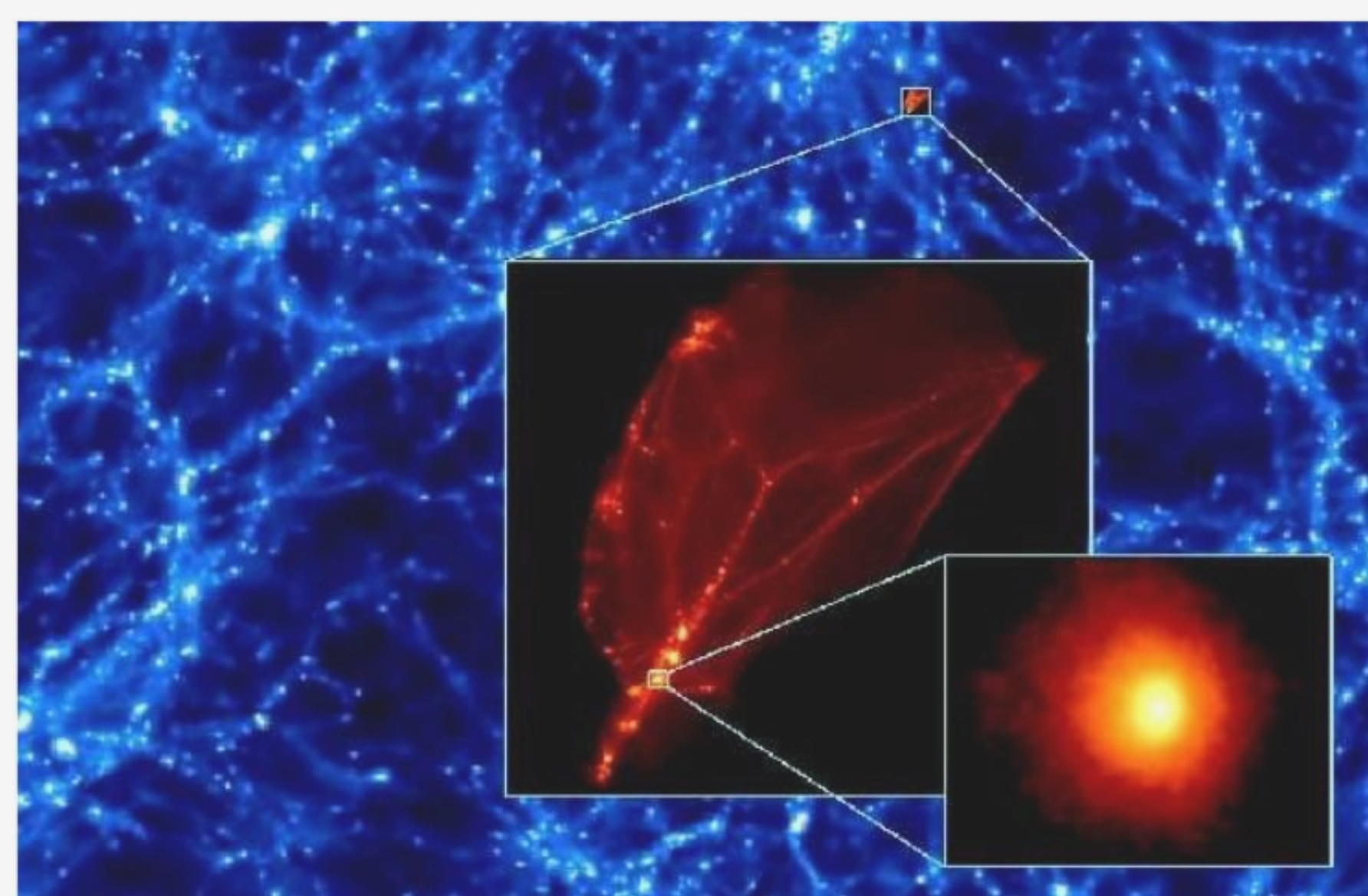


Figure 1 Computer simulations have provided evidence for the existence of dark matter clumps, shown in this image. Based on these simulations we believe that these clumps should still exist today

THEORY

- There are 5×10^{15} clumps in our galaxy
- There are 100 billion binary star systems
- Binary systems and clumps should interact
- Interactions lead to dark matter captured
- Leads to an increased dark matter density in the binary star system
- Dark matter self-annihilates, leading to a release of energy
- Two possibilities:
 - Dark matter scatters off of stars and gradually accretes in the center of stars, and the energy released makes the stars hotter and brighter
 - Dark matter can annihilate and release energy in the entirety of binary star systems, creating a gamma-ray source in a binary system

CAPTURE EVENTS

Need to conditions for mass to be captured:

- 1) The dark matter has to go through the ellipse defined by the binary orbit
- 2) The speed of the clump relative to the binary system must be less than the speed of the binary stars around each other

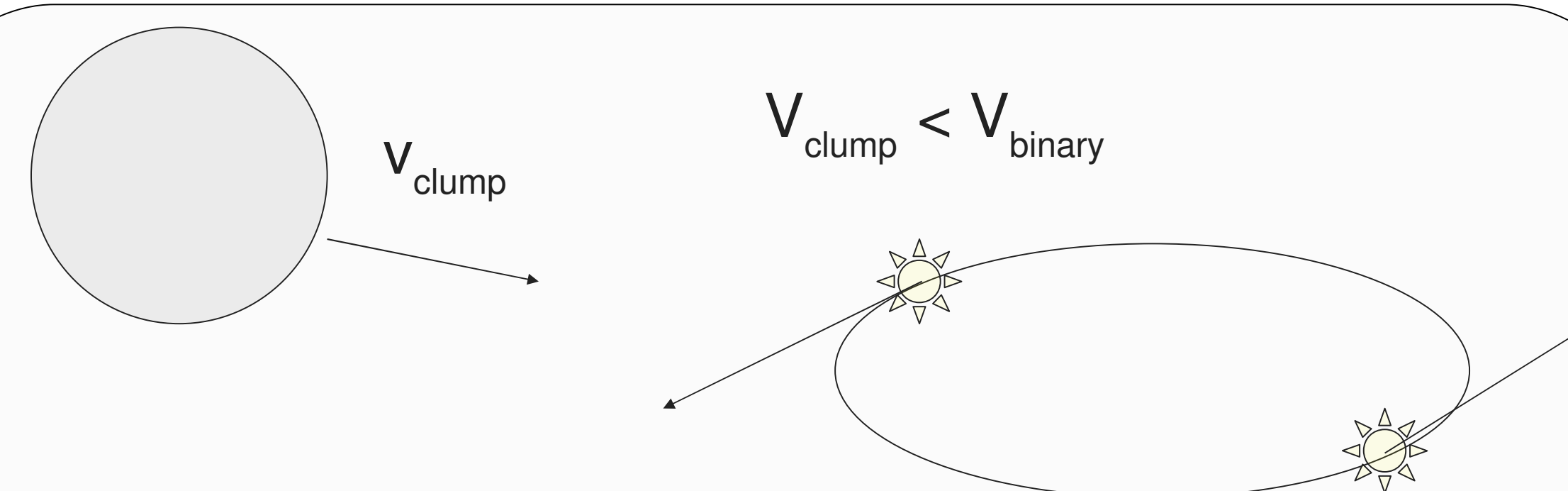


Figure 2 – The capture of a dark matter clump. The clump must be going through the binary orbit at a slow enough speed for any mass to be captured. Otherwise, the clump will simply continue traveling through the galaxy

CAPTURE RESULTS

- One capture every 500 years in our galaxy
- Roughly 20 million capture events have occurred

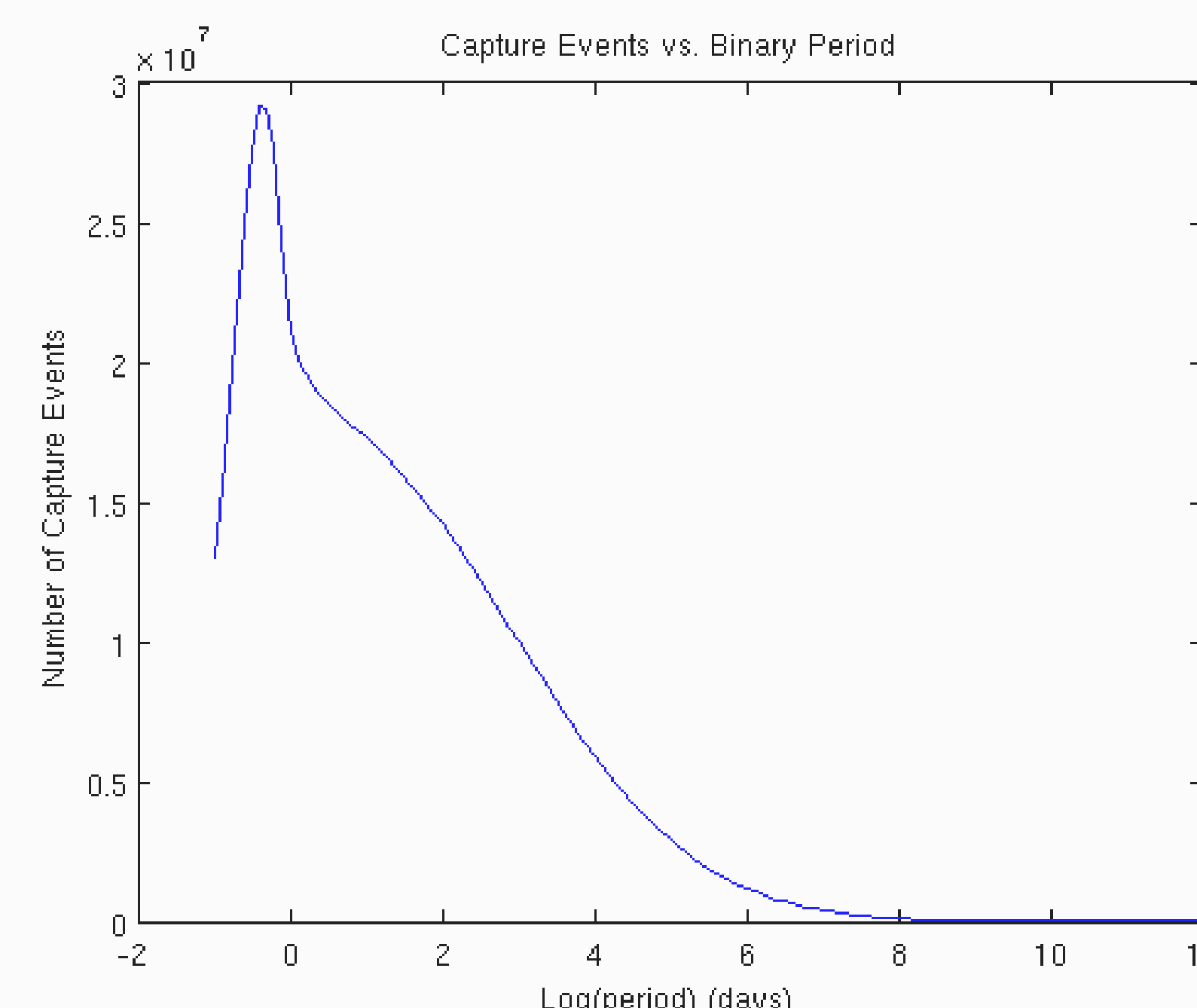


Figure 3 – Plot of the number of captures for a given binary period. The total number of captures is about 20 million

MASS CAPTURED

- What we really want is the total mass captured
- This depends on many variables:
 - Binary period
 - Clump speed
 - Two angles that determine the clump direction
 - Three angles that determine the projected area of the binary orbit for the clump to interact with
 - The mass of the clump
 - The impact parameters of the clump relative to the binary orbit
 - The intersecting volume of the clump that goes through the binary orbit
- We integrated over all these variables numerically and got the following mass distribution:

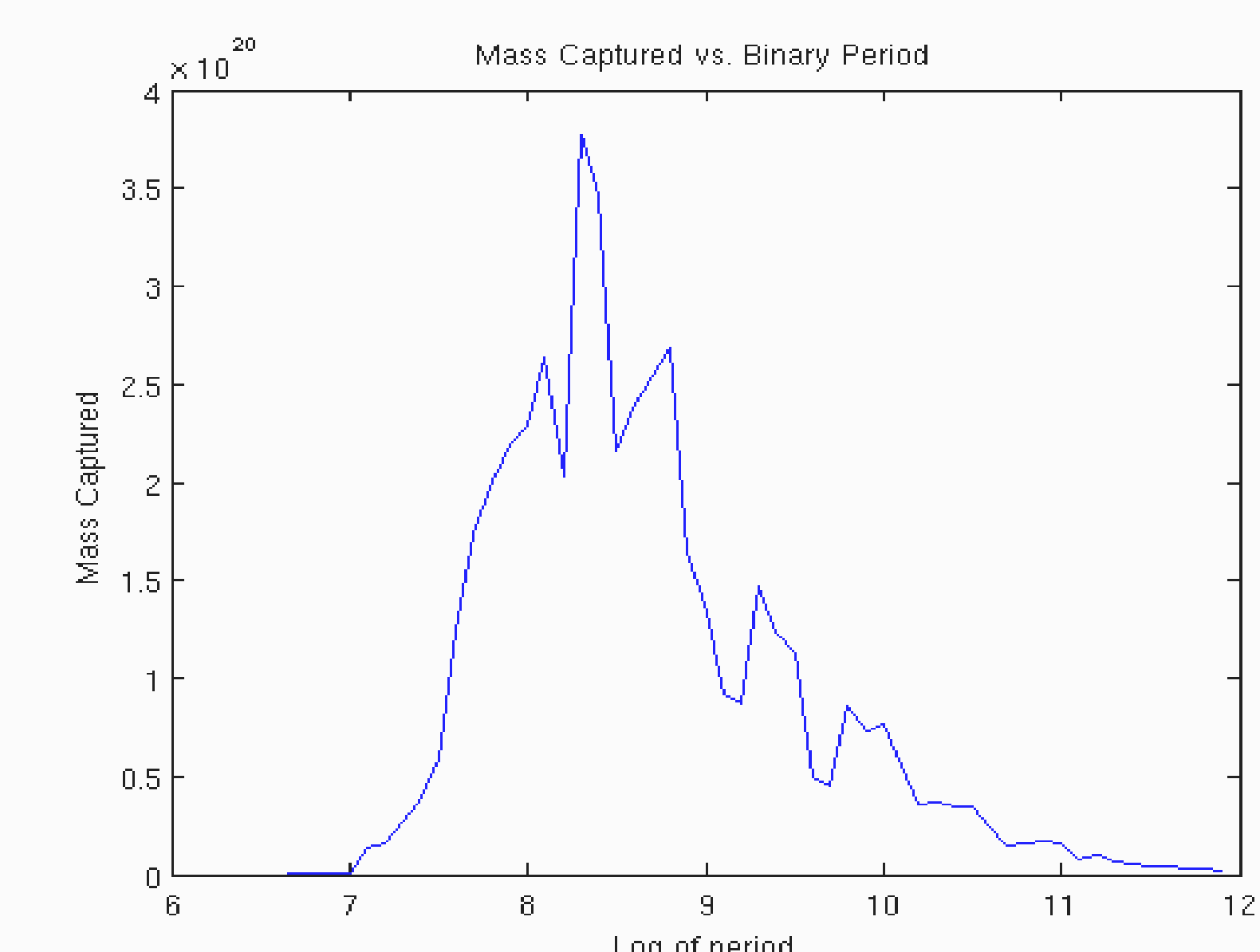


Figure 4 – The mass captured vs. the binary orbit period

CONCLUSIONS

There is a significant amount of dark matter captured in certain binary star systems. This captured mass could be detectable either by looking at the increase in luminosities of the binary stars or by looking for gamma-ray emission from binary star systems. Seeing either of these effects would be equivalent to indirectly finding dark matter.

ACKNOWLEDGEMENTS

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REFERENCES

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Diemand, Moore and Stadell, "Earth-Mass Dark-Matter Haloes as the First Structures in the Early Universe."