Oort Cloud Evolution in Star Clusters

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INTRODUCTION

Stars and planetary systems do not form in isolation, but in clustered environments within a galaxy such as a collection of stars known as a star cluster. Clusters can dissolve into stellar streams which is when the stars in the cluster space out into a stream-like path. The escape time (t_{esc}) of a star from a cluster is the time it leaves the cluster to join the stream.

An Oort Cloud is a theoretical cloud of cometary objects that orbit a star in the outer regions past its planetary system. The evolution of orbiting objects around a star within a star cluster such as comets in an Oort Cloud can be affected by perturbations from nearby stars which is what is being investigated in this project.

MOTIVATION & GOALS

Question

When do Oort Clouds form around a star, are they formed during the time a star is first formed within a cluster or after?

Prediction

Predict that most of the Oort Cloud forms after the cluster phase, because otherwise it would be difficult for comets to survive within such a crowded environment.

Main Goals

Observe how an Oort Cloud of a star within a star cluster evolves over time and see if or how long it can survive by observing if comets can stay in orbit without being ejected due to gravitational interferences from other stars.

SIMULATION METHODS

Star Cluster:
- 7500 M⊙
- Initial half-mass radius: 4 pc
- Circular orbit at 10 kpc in Milky-Way type galaxy

Oort Clouds:
- Massless comets orbiting one M⊙ star
- Semi Major Axes : 107.71-10771AU

Chosen M⊙ Stars:
- Star with early escape time (t_{esc} = 167.45 Myr.)
- Star with late escape time (t_{esc} = 1.046 Gyr.)

Simulation Code: Lonelyplanets → NBODY6++GPU, REBOUND
- Four simulations of each Oort Cloud but with different start times and same end time of 1.5 Gyr.

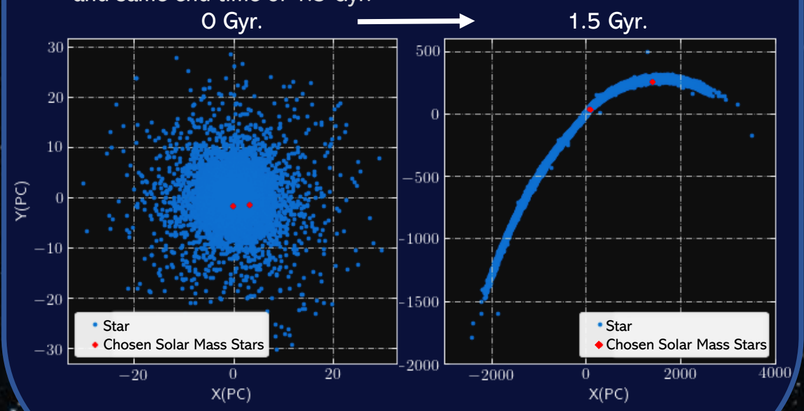

Fig.1 & 2: Star cluster at 0 Gyr. (left) and 1.5 Gyr. (right)

RESULTS

Simulation Start Time	Percent of Comets Ejected		
	100 Comet Sims	1000 Comet Sims	
	Late Escape Time	Early Escape Time	Late Escape Time
#1: 0 yr.	23%	2.2%	30.3%
#2: 250 Myr.	11%	0%	17.1%
#3: 500 Myr.	9%	0%	14.8%
#4: 750 Myr.	9%	0%	10%

MAIN OBSERVATIONS
- Comets more likely to be ejected closer to the start time of their simulation
- Some perturbations eject more than one comet at a time
- All comet ejections stop after the star leaves the cluster

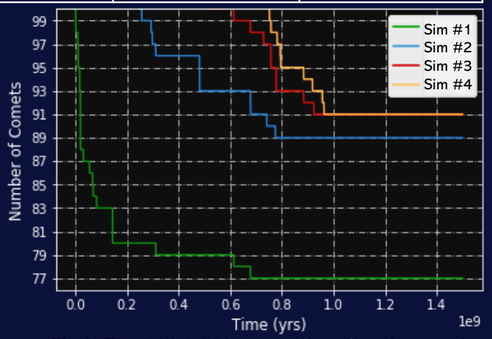

Fig.3: The initial 100 comet Oort Clouds over time

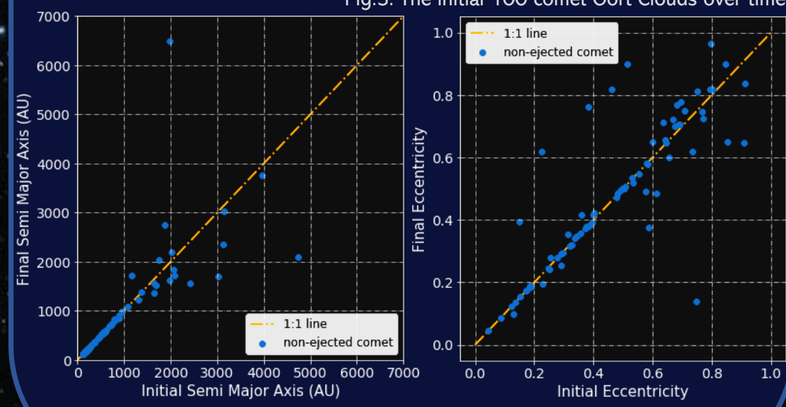

Fig.4 & 5: Initial versus final semi major axis (left) and eccentricity (right) of non-ejected comets for sim. #1 of 100 comets

CONCLUSIONS

- Majority of the comets in the Oort Clouds simulated survive
- For simulations starting inside the cluster: only comets with smaller initial semi major axis values (closer to the star) survive while the rest get ejected
- No comets are ejected once a star escapes the cluster into the stream, simulations starting later than the star's escape time have zero ejections
- More simulations of Oort Clouds around M⊙ stars in the cluster are planned to make further conclusions

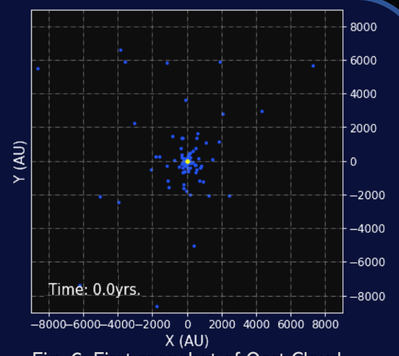

Fig. 6: First snapshot of Oort Cloud sim. #1 of 100 comets

OORT CLOUD ANIMATIONS

Click Here or Scan: