

# Could Pluto and Charon's Moons Have Been Captured?

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# How did Pluto's smaller moons form?

- In the framework of the nebular hypothesis, the Pluto system and the Kuiper belt objects (KBO) formed out of colliding icy planetesimals.
- Pluto's moons have very low eccentricity, meaning that they likely formed out of a debris disk orbiting Pluto.
- The creation of such a disk is difficult to explain with an object possessing as little mass as Pluto.



# Could Pluto's moons have been captured?

- In the case of two body interactions, all orbits are either elliptical and permanent, or hyperbolic or temporary.
- This means that gravitational capture does not allow for the capture of moons by a single central object.
- If Charon had already formed before the rest of the moons, interactions with other Kuiper belt objects are now three body interactions, which are more complicated.

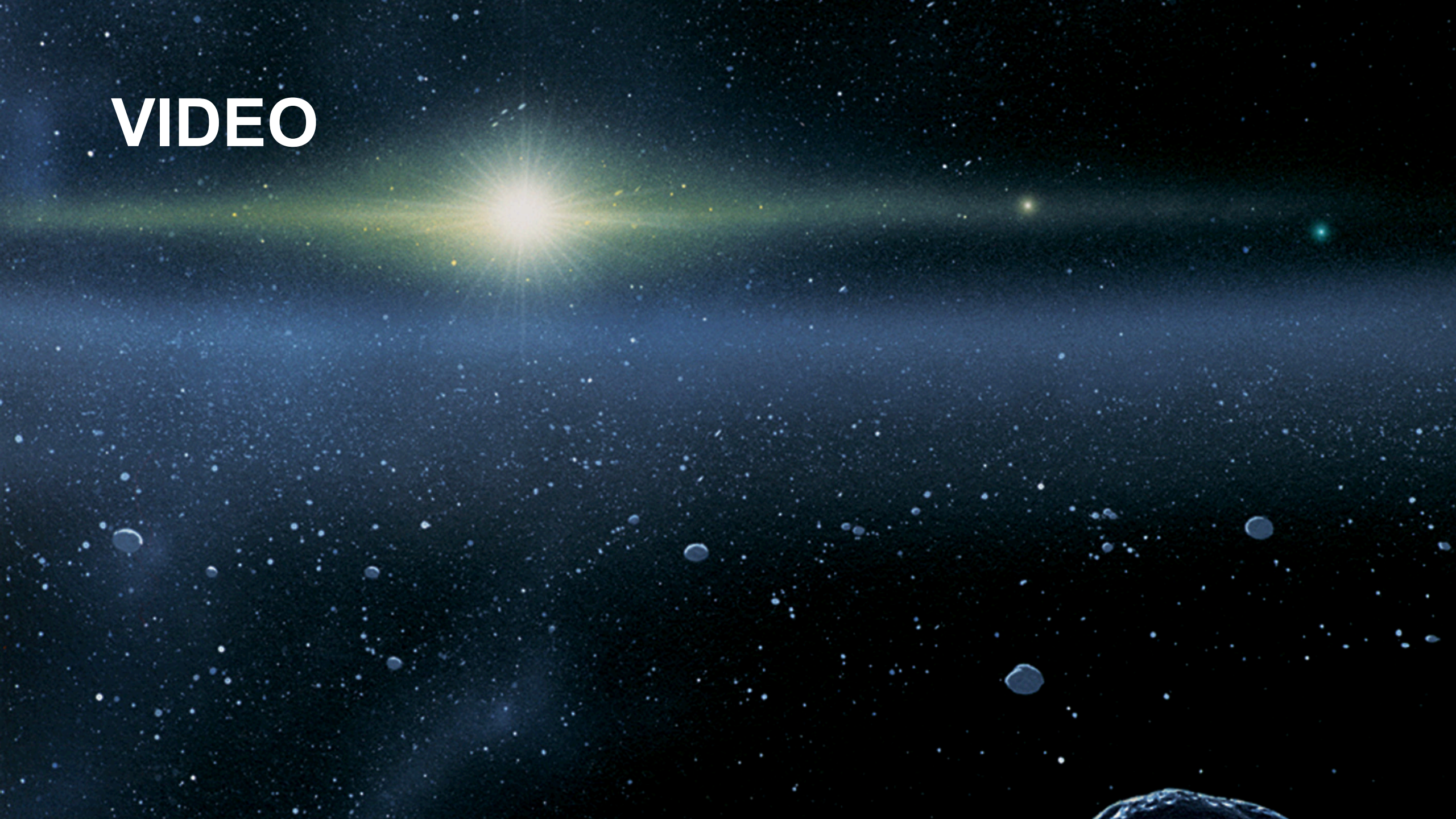


# Method

- The simulations were run on a leapfrog n-body code (Hartley, 2014)
- A randomly generated cloud of Kuiper belt objects with conditions expected in the early solar system are initialized moving towards the Pluto Charon system.
- These objects are tracked individually until they exit the hill sphere of the Pluto-Charon system.



**VIDEO**





# Could Pluto's moons have been captured?

- In the case of three body interactions, energy may be exchanged between the three objects, allowing for outside objects to drop to the negative energy necessary to become gravitationally bound.
- This energy exchange happens in both directions, and all objects which become bound will eventually depart the system.
- Objects remain bound for 10s-100s of Earth years on average.



**PICTURE**





# Bound and unbound KBO interactions

- KBOs which are temporarily bound to Pluto through three body energy exchange may collide with free KBOs.
- These collisions produce debris disks which could collapse to form the outer moons of Pluto
- Hypothetical migration of the gas giants may mean that the Kuiper belt was thousands of times more populated than it is now, making such collisions much more likely



# Bound and unbound KBO interactions

- A statistical analysis of possible collisions was done with bound states discovered with
- Even with generous estimates of the lifetime and density of the early solar system Kuiper Belt, collisions of bound and unbound objects are exceedingly unlikely.
- It appears that this method fails to produce the moons.