<u>Cosmic Shooting Gallery</u>

New Mexico
Supercomputing challenge
Final Report
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Team 42
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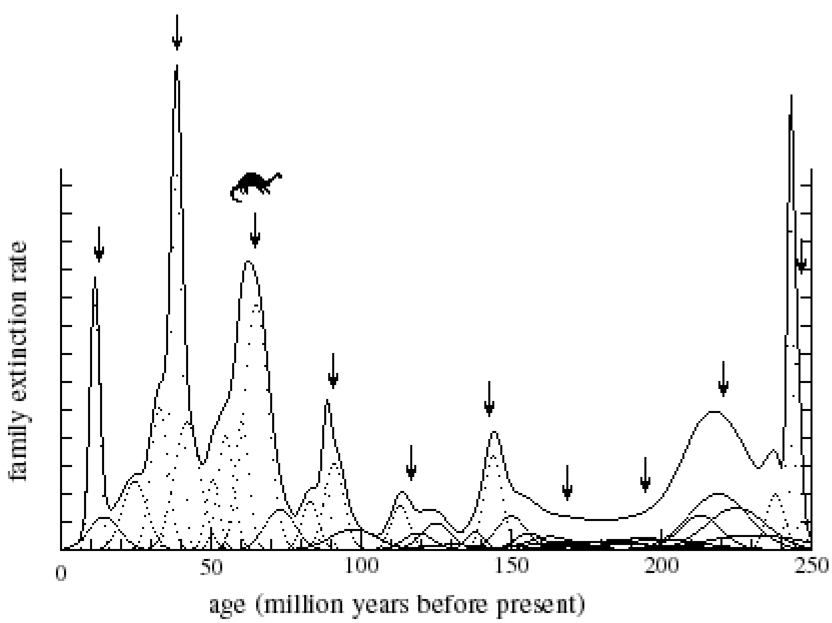
EXECUTIVE SUMMARY

When researching the cause for the mass extinction of the dinosaurs 65 million years ago scientists found evidence that our planet goes through sterilization about every 26-30 million years. This periodicity of the extinctions led to the theory that our sun has a counterpart. Richard A. Muller developed Nemesis Theory which states the possibility that our solar system is part of a binary system. Muller believes Nemesis has an orbit that passes though the Oort cloud which is a collection of left over material from the creation of our solar system. When Nemesis's orbit travels into the cloud it sends thousands of particles our way, essentially putting our planet in the middle of an inter-planetary shooting gallery.

The purpose of the project was to verify the cogency of this theory and draw conclusions as to where, how and why this star exists. By creating a model that shows the orbit of Nemesis we were able to evaluate the necessary characteristics for the existence of this binary, including its mass, distance and velocities, while looking at any other possible parameters (e.g., variations from projected values).

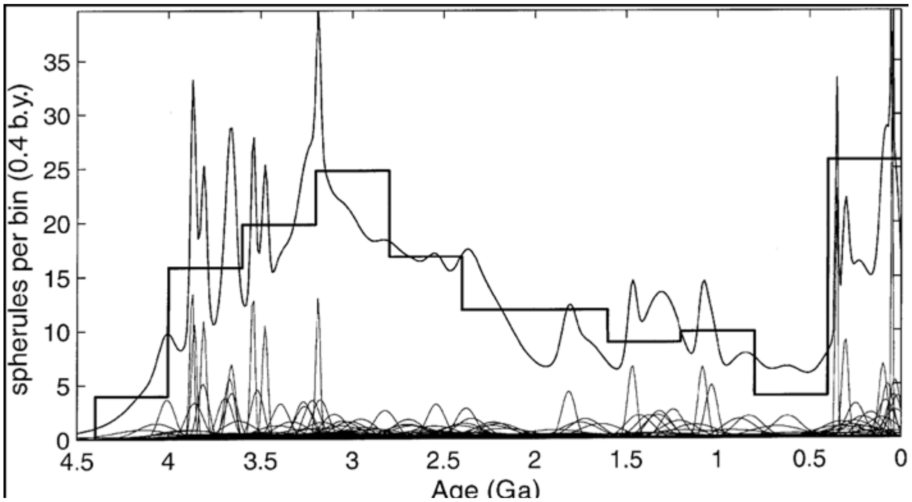
Nemesis theory originated with the discovery that a giant meteor or asteroid was responsible for the extinction of the dinosaurs. Louis Alvarez made a discovery that a thick layer of iridium lined the space between the rock strata of the Mesozoic and Cenozoic eras. What they proposed was that these unusually high levels of iridium were in fact the left over debris of an impact that occurred 66.4 million years ago, which was suggested to be the cause of the extinction of the dinosaurs. ("Encyclopedia", Alvarez) After much scrutiny the theory became the most widely accepted explanation of the cause of this mass extinction event. Evidence showed that this was not an isolated event, but part of a cyclical process occurring every 26-30 million years. By analyzing the marine fossils of various genus species of over 13,000 generic extinction events John Sepkoski and Dave Raup were able to determine the periocity of these extinctions. The following chart shows the statistical analysis of the projected extinction rate over time (a scope of 270 ma), as concluded by John Sepkoski and Dave Raup. ("Proceedings". Sepkoski)



The peak at 11 MA is slightly exaggerated due to the need to create the present at a zero percent impact event. Each arrow represents the 26 million year mark, which shows that there is an obvious periocity. Although this theory does explain a known periocity it gives no suggestion as to the cause of these events.

Richard Muller proposed a theory, known as Nemesis theory, which stated that the cause of this periocity lied in the notion that our sun is part of a binary star system and that this companion star passed directly through the Oort cloud. This ring, composed of left over planetary debris from the creation of our solar system, is almost out of the sun's gravitational reach. The loosely held debris is postulated to be the location where Nemesis reloads and sends objects into the inner solar system. Nemesis is believed to be a Jupiter sized planet or a red dwarf star with a magnitude of 7-12.

The research done by Muller extends beyond the dating of fossils to the Apollo 14 landing site on the moon. Small granules of molten glass remain on the surface of lunar impact craters, and the dating of these small "spherules" has maintained that there is a periocity between these impacts. The distribution of these spherules is vast (100 spherules to 1 gram of lunar soil), and originates from several different impact events. ("Measurement". Muller). Although it would be impossible to determine the asteroid the spherules originate from, the data shows that there is a cyclical occurrence of lunar impacts that occurs on a 26-30 million year basis. As one scientist had pointed out, there is a possibility of variation or perturbances of comet showers due to the effect of passing star and planet orbits and gravities. The first 12 soil samples gave little precision as to the age variation, as the soil contained low levels of potassium levels necessary for precision, resulting in a variation of more than 1 billion years. These uncertainties were ameliorated by collecting samples from a know impact site to contain higher levels of potassium (increase of a factor of about 5-10), giving them the higher precision needed.



The above chart shows the age distribution of the lunar spherules collected at the Apollo 14 landing site as stated by Richard Muller. At around the 4 Ga mark you can see a drastic increase in the amount of spherules present, denoting some possible shift in the parameters of the Nemesis object.

Muller stated that this star is most likely orbiting about 3 light years away orbiting at a 26 million year cycle with an eccentricity of .5, meaning that its orbit passes close enough to the Oort cloud to create an impact-causing disturbance. Many scientists believe that an orbit at a distance of 3 light years is unstable, as that is vastly larger that the orbits of known binary systems. Studies done by Hut show that the behavior of Nemesis could experience massive disturbances by nearby passing stars, alleviating suspicion of the fact that Nemesis' orbit post-dates the creation of our solar system. ("Measurement". Muller)

Scientists scrutinized that there is a sudden increase in the distribution of lunar spherules at the Apollo 14 landing site (see chart on spherule distribution). Muller responded by stating that the orbit of Nemesis pre-4ga was a more circular orbit, and became elliptical after the passing of a massive star (probably less than 1 light year away). This disturbance very well could have occurred within the lifetime of our solar system and probably did occur at the 4ga time mark, explaining the increase in spherule distribution (denoting an increase in impact events).

What was concluded from the collection of lunar spherules was that there was insufficient evidence as to the age accuracy of Nemesis (in explaining the 26 m.y. cycle). The orbit of Nemesis was altered drastically, explaining a heightened distribution of lunar spherules (occurring at 4ga), and the orbit of Nemesis is potentially stable. Nemesis would be visible with a medium sized telescope but hasn't been found due to the fact that Nemesis would (most likely) be a red dwarf that blends into the background of stars.

PURPOSE

In choosing this project our team would develop the ability to use mathematical figures and equations to create a computational model of a certain situation. We would be able to take historically known facts and verify with significant precision whether or not collected data reflects a possible real-world situation. The topic is of scientific importance, not only to specialists, but the people of our society of which these events effect (i.e., the whole world) and has received little acknowledgement among laymen. By choosing this topic we add further validation to controversial theory.

METHOD

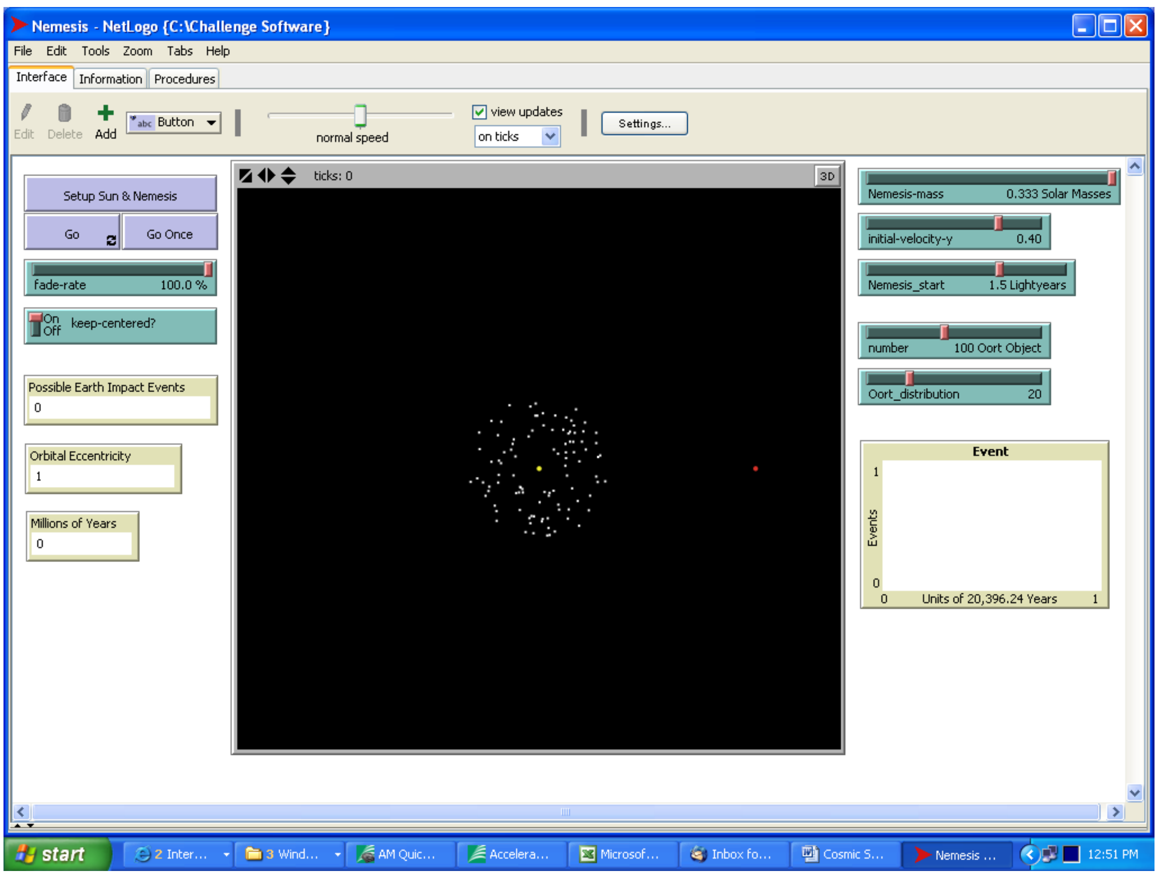
The purpose of the Nemesis Model was to use the research gathered to replicate the interactions of Nemesis with our solar system, and especially the Oort cloud, to corroborate a speculated cause for the periocity of extinction events. Using an agent based software title NetLogo, the team created a discrete model of the Nemesis theory. This model was used to gather the required data needed to create a possible scenario for the Nemesis theory.

We conducted several trial runs in which we altered the distance, mass and orbital velocities, giving a statistical analysis of specific variable conditions necessary for the existence of Nemesis. The program's event graph can be exported into a excel spread sheet, in which each spread sheet lists all setting of the particular test run. The spread sheet then can be turned into a graph showing at what tick a possible impact occurred. This graph was used to examine our researched data being tested to see if we could recreate the hypothesized periocity of extinction events.

THE MODEL

The observing area allowed by NetLogo forces the scaling of our model to exclude the Planets. The outer orbit of Pluto is only 1/16th a single patch. 200 patches on the screen amount to 3 1/3 light years of travel. Every 60 turtle steps makes up a single light year. The Star in our system and the Nemesis star are represented by 2 pixels objects, and the Oort objects are left at one pixel for ease of visual reference as all objects on the screen would be invisible at this scale. Each Oort turtle is a representation of thousands of possible objects potentially heading for earth. To achieve a finer conclusion the use of a super computer will be needed to handle all of the clients in the model.

The main screen of the program has several buttons and sliders that allow the user to change the variables in the code. The user can manipulate set values for Nemesis's mass ranging from .0010 solar masses (approximately the mass of Jupiter) to .333 solar masses (one third the mass of our sun). The program lets the user adjust Nemesis's initial orbital velocity. The starting position of Nemesis can be adjusted from half a light year to two light years away.



The user has control of several aspects of the Oort cloud. The user can adjust the number of possible Oort's in the cloud and the distribution of the cloud. The main screen has several counters; one to count the millions of years the model has run the model will automatically stop at 400 million years. Nemeses calculated orbital eccentricity, and the number of possible earth impacts. The model has a graph recording the time of each possible Earth impact.

Our Model is based off a Netlogo model that came with the built in library. The N-Bodies model had a two planet set up which we used. The code was altered but much of the stayed the same. The “turtles own” variables have been left unaltered but several “globals” have been added. The setup procedure was changed to represent the Theory’s elements and their properties. The run time procedure was modified so the model would be able to count and plot the possible impact events. The run time procedure in our version calculates the orbital eccentricity by finding the Apoapsis (r-a) and the Periapsis (r-p) of Nemesis to our Sun.

The Code

```
turtles-own
[ fx     ;; x-component of force vector
  fy     ;; y-component of force vector
  vx     ;; x-component of velocity vector
  vy     ;; y-component of velocity vector
  xc     ;; real x-coordinate (in case particle leaves world)
  yc     ;; real y-coordinate (in case particle leaves world)
  mass   ;; the particle's mass\

]

globals
[ center-of-mass-yc ;; y-coordinate of the center of mass
  center-of-mass-xc ;; x-coordinate of the center of mass
  g  ;; Gravitational Constant
  Event ;;Sum of possible near Earth events.
  Ev  ;; count current events for plot
  r-a  ;;  Apoapsis of Nemesis (farthest distance to the Sun)
  r-p  ;;  Periapsis of Nemesis (closest distance to the Sun)
  ex  ;;  Orbital  Eccentricity
  cnt ;; counter for collision loop
]

;;;;;;;;;;;;;;;;;;;;;;
;;; Setup Procedure ;;;
;;;;;;;;;;;;;;;;;;;;;;

to setup-two-planet
  ca
  set g 14
  set-default-shape turtles "circle"
  set event 0
  set ex 1
  ;;Creates the Sun
  crt 1
  [ set color yellow
    set mass 1
    set size 2
  ]
  ;;Creates Nemesis
  crt 1
  [ set color red
    set mass Nemesis-mass ;;slider
    set size 2
```

```
   set xc (Nemesis_start * (60) ;;slider
   set yc 0
   set r-a xc
   set r-p xc
   setxy xc yc
   set vx 0
   set vy initial-velocity-y ;;slider
  ]
  ;;Creates an Oort Cloud
  repeat number [crt 1 ;; slider
          [ set color white
            set mass .00000000000000001
            set size 1
            lt random 360
            fd ((random Oort_distribution ) + 10) ;;slider
            set xc xcor
            set yc ycor
            ;;Gives Oort particles circlular orbits
            let dist sqrt ((xc * xc) + (yc * yc))
            set vx (-1 * sin ( atan yc xc ) * (sqrt( g / dist )))
            set vy (cos ( atan yc xc ) * (sqrt( g / dist )))
          ]
        ]
end

;;;;;;;;;;;;;;;;;;;;;;;;;
;;; Runtime Procedures ;;;
;;;;;;;;;;;;;;;;;;;;;;;;;
to go
  ask turtles
  [ set fx 0
    set fy 0
  ]
  ;; must do all of these steps separately to get correct results
  ;; since all turtles interact with one another
  ask turtle 1 [ update-eccentricity ]
  check-for-collisions
  ask turtles [ update-force ]
  ask turtles [ update-velocity ]
  ask turtles [ update-position ]
  if keep-centered?
  [ recenter ]
  fade-patches
  tick
  if ((ticks * 20396.23549)/ 1000000) > 400 [stop]
end
```

```
to check-for-collisions
  set cnt 2
  set Ev 0
  repeat number
  [ ask turtle cnt [if distance turtle 0 < 3 [
    set event event + 1 set Ev Ev + 1 ]]
    set cnt cnt + 1
  ]
  set-current-plot "Event"
  plot Ev
end

to update-force ;; Turtle Procedure
  ;; This is recursive over all the turtles, each turtle asks this of all other turtles
  ask other turtles [ sum-its-force-on-me myself ]
end

to sum-its-force-on-me [it] ;; Turtle Procedure
  let xd xc - [xc] of it
  let yd yc - [yc] of it
  let d sqrt ((xd * xd) + (yd * yd))
  if d > 1[
  set fx fx + (cos (atan (- yd) (- xd))) * ([mass] of it * mass) / (d * d)
  set fy fy + (sin (atan (- yd) (- xd))) * ([mass] of it * mass) / (d * d)
  ]
end

to update-velocity ;; Turtle Procedure
  ;; Now we update each particle's velocity, by taking last time-step's velocity
  ;; and adding the effect of the force to it.
  set vx (vx + (fx * g / mass))
  set vy (vy + (fy * g / mass))
end

to update-position ;; Turtle Procedure
  ;; As our system is closed, we can safely recenter the center of mass to the origin.
  set xc (xc + vx)
  set yc (yc + vy)
  adjust-position
end

to adjust-position ;; Turtle Procedure
  ;; If we're in the visible world (the world inside the view)
  ;; update our x and y coordinates.
  ;; if there is no patch at xc yc that means it is outside the world
```

```
  ;; and the turtle should just be hidden until it returns to the
  ;; viewable world.
  ifelse patch-at (xc - xcor) (yc - ycor) != nobody
  [ setxy xc yc
    show-turtle
    if (fade-rate != 100)
    [ set pcolor color + 3 ]
  ]
  [ hide-turtle ]
end

;; Center of Mass
to recenter
  find-center-of-mass
  ask turtles
  [ set xc (xc - center-of-mass-xc)
    set yc (yc - center-of-mass-yc)
    adjust-position
  ]
end

to find-center-of-mass
  if any? turtles
  [ set center-of-mass-xc sum [mass * xc] of turtles / sum [mass] of turtles
    set center-of-mass-yc sum [mass * yc] of turtles / sum [mass] of turtles
  ]
end

to fade-patches
  ask patches with [pcolor != black]
  [ ifelse (fade-rate = 100)
    [ set pcolor black ]
    [ if (fade-rate != 0)
      [ fade ]
    ]
  ]
end

to fade ;; Patch Procedure
  let new-color pcolor - 8 * fade-rate / 100
  ;; if the new-color is no longer the same shade then it's faded to black.
  ifelse (shade-of? pcolor new-color)
  [ set pcolor new-color ]
  [ set pcolor black ]
end
```

```
to update-eccentricity

  let d distance turtle 0
  if d > r-a [ set r-a d ]
  if d < r-p [ set r-p d]
  set ex (( r-a - r-p ) / ( r-a + r-p ))

end
```


RESULTS

The information gathered from our model states that if Nemesis was a large Jupiter size planet the interaction with the Oorts would be miniscule. The best size we found in our model was our sister star need to be from a quarter our star to a third our star.

In simulating the orbit of Nemesis we were at this point unable to conclude a set of specific values the orbit of Nemesis would depend on. To obtain this data we will run many more simulations before the Challenge Expo and hope to develop enough statistical evidence to accurately say on what values the orbit depends. The model that we have created will enable us to verify the possible values for the orbit, as illustrated in the simulations we have conducted. In figure 1 we see there is a periocity of impact events, just not the periocity that has been historically recorded.

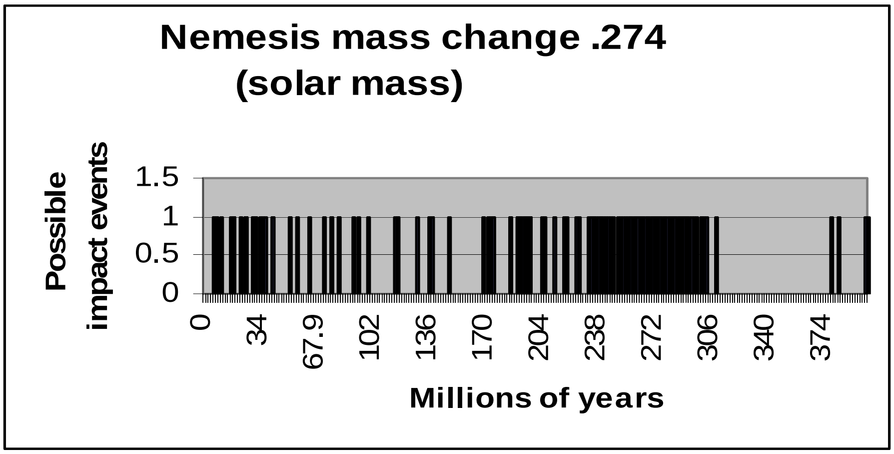


Figure 1. Nemesis size: .274 Initial Velocity: .40 Distance 1.5 light years
Oort cloud distribution 50 Oort count: 200
Impact events heavy throughout

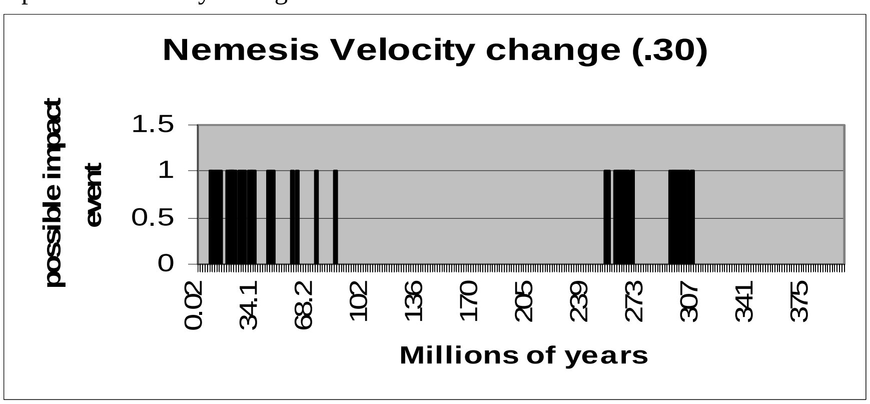


Figure 2. Nemesis size .333 Initial velocity .30 Distance 1.5 light years
Oort Distribution: 20 Oort count: 200
No clear periocity of impacts

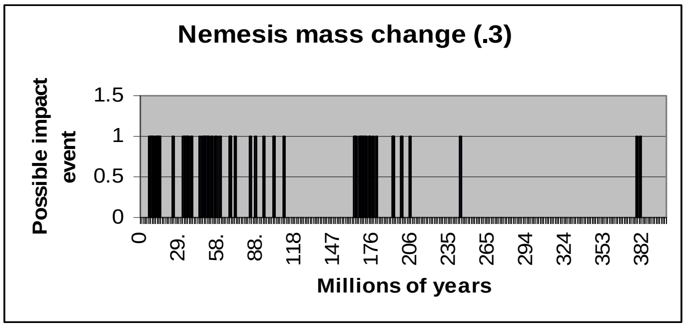


Figure 3. Nemesis size: .3 (Solar mass) Initial velocity: .4 Distance 1.5 light years
Oort Disribution: 20 Oort count: 200
Heavy amounts of activity thought the middle with a large event later on
No distinctive periocity of events

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