Physics reserch notes

agama

1. You have to install it with terminal
2. Go through examples get it installed
    1. Nobody
    2. Particle spray
    3. The rate at wish stars leak out of globular cluster
    4. When its passing through the disk and passing through there center it sees more tidal effects
    5. It is likly to change its star shedding
    6. When trapped in the bulge you think it woudl have a higher disillusion rate
        1. If its been trapped for billions of year
    7. 10-13 billion years
    8. The ones closer t the bulge tend to be richer in h every elimental
    9. They also are donated by warm
    10. What percent of the metal poor stars have been striped from globular clusters
3. Starting with example tidal stream
    1. You need a c compiler
    2. You need python (3)
    3. you need git

virial theorem.
Modulates the shedding of stars through energy

What is a globular cluster? It's a spherical swarm of stars ~10^6 stars very old
a galaxy is a cluster of stars and black holes, dark matter, planets, and such. In order to modulate, we need the force of the galaxies acting on the globular cluster. We view it as a continuous distribution of mass.
We need a galactic potential to give us a force on the globular cluster, then we can get the orbit and tidal distribution.

intuation

review basic tidal theory
the idea is that each point on a object experiences a different foce

thinking about the galactic potential
Φ is made of dark matter which we think of as the NFW potentual which comes from their names, there is a bar disc and bulge
dose the bar get shortter ?

Most of the Milky Way is dark matter ? How much is dark matter?
Look up NFW profile.

what are the plummer and king models
It is a model of the potential of the global clusters themselves.

how many there are 150 globular clusters I was wondering about the risk of dealing with stars that are in the wrong place spectroskpy data

potential for the

question distance across the average globular clusters what is their size, distance across and such

like to install these codes
-python 3.x version
-numpy
-scypi
-matplotlib
-pandas
-astropy
-gala
-galpy
-agama
-pyfalcon

talking about reserch strucure
class is directed, and you have a problem and you solve it
you arnt given a sheet of problem with a papper instead its difrent
you dont know what to do thats normal
you are going to code and you are going to have errors and fail

tidal forces next week
mwpotentuleHunter24

Verification tests there was a long process to create the tests they created
Pal5 was a halo cluster

They

Liller1 and turban and 5
1E6 size clusters
1.01E6 solar masses
lkiller parsec from the golatic center
It has ellments of Iron

We think they are reminates of
They come from

They think that these clusters have had many difrent prepress of stelae y gro

1. what she needs is the mass los from 69, 65
2. 65-59 is likly confined to the bludge and has been for a while
3. we think difrent radial velocties may not matter as much
4. the bar rotats difrent to stelar populations and clusters "it kiskcs " its efecting the tidal radisus
5. what cant be done with out propper nbody simulations is how much mass its losing
6. particle sprey was for mcmc analysis, for single runs we can get away with nbody simulations we can likly upscale the numer of particles and its not goign to take
7. get ptar or nbody 6 working
8. the other thing to mention
9. all the globular clusters in our galixes are over 10 billion years old
    1. so when running nbody code, all the stars are one solar mas or less
    2. larger starts are much further back in time
    3. trying to evolve them they are imortal stars going suppernova ?
        1. this doent help us going abck into the past
10. two populations inner and outer halo
    1. inner has bludge clusters they are being constantly shocked and
    2. outer ones they dont enter the central regions mostly, most tidal shoching comes from the disk
    3. your looking at a penut of the bludge ?
    4. bdbs survay
        1. there are at least clusters in this star feild but you can see how messy it is
        2. we have acess to all the spectrospoic data we ahve about 1000 spectra but also includes these aries, didnt do things with the data that didnt have
        3. to first order we use the metilicty we use irnon in a log cluster, ie 1 is sun, -1 is 10 times les -2 100 times les
        4. most of the ones in the suns orbit are
        5. the ones that have spread and iron abundence arnt from the milkway way, they are
        6. even globular clusters that arnt___\have at least 2 star clusters
            1. they have old stars from ther begining
                1. the second pupuliton comes from the death of the larger stars, its concentrated closer to the cenrter of the cluster, which isnt sceen next to the field stars
            2. clusters formed fast so the enviroment today dosent suport fast stars so they and enogph meteril is mantained to
            3. started with a million stars, stelera evilution goes fast for masive stars
            4. stelar mass funciton, it forms sars 30% of the mass of the sun few million years they becomd supper gaints and supper novey 20 solar mases may only take 100 thousand years and a few million
            5. 10 to 30 million years
            6. 10 solar masses

7. gia gives you paralax which is tringulations data
8. apo center as far as it gets away 6965
9. learn what the legramge points are ohh I see
10. we need to make it work with pall 5 then we need to try 6965
11. in agama there is a way to moddle the changes in tidal radisus

7. barns hut tree
8. start with the oct tree
9. special funcitons coding sterlar evilution how much mass to lose
10. look into globular cluster tidal shocking most important pappers
11. mathmatics of tidal shocking
12. Focusing on changing perspective map celestial coordinates to galactic coordinates
13. python function that maps celestial to galactic coordinates

type	volume	surface area	mass	
one sol	1.41	6.07 x 10^{12} square kilometers	1.989 × 10^30 kg	

joes note book agama galatic dyanmics code
You later have to rescale all masses when you set your G to be 1
the tida radisus is the distance at which the stars are striped. I would like to manually calculate through the King models.

whats the distribution of dark matter in the galatic potentule halo
dynamical friction
given a grid of boddies evenly distributed a body with v0 passing throuhg the grid will lose energy to the drag
chandrasalacr dynamic friction need to learn the wake method aswell

1. we need a numarical intigration speed
    1. globular cluster is a bloonch of stars
    2. each particle i has its own 3 dimensal postion and velocity
    3. potnetule host =potentual dark matterPotentual +bluge+dissk
    4. the force on each particle is equal to F_i=sum
    5. we need second dirivitives
    6. the tidal tensor
        1. the difrencel force oacross a extend body is equal to the
        2. learn how to take second drivitive
        3. learn how tidal stripping is related ot the tidal
        4. hesian is the seocnd drivitive
        5. throught the forces we want to update the trajectory of the object for all stars
        6. introduciton ot numarical intigraiton this is thr eulier method
            1. euler is the simplest method to solve it method for O.D.E

2. simpels method good for intuation
3. $\frac{dy}{dt} = -y$ we call this exponetual decay
4. $\frac{\Delta y}{\Delta t} = -y$

```
import numpy as np
import matplotlib.pyplot as plt

y0= 100
dt=.1
data=[]
for i in range(100):
    y0= y0-y0*dt

    data.append(y0)

ax=plt.subplot()
ax.plot(data)
plt.show()
```

Leap frogging is symmetric. We will use it
esp used for softining
how to compute the stars that have positive energy from the perspective of the cluster
standerd leep frog is not good here because stars are very close, so we need a much smaller time step.

$\frac{dy}{dt} = f(t,y), y_0 = y(t=0), (1)$ this is the first order ordinary diffeerital equation the goal is to find the solution to y(t) for all t on the interval of interest
Given the ode and the initial condition $y(t=0) = y_0$ in physics we solve f=mg and f=ma=mdx/dt^2
The kinematic equations is a second order ode, second order ODE second order due to the dx
The solution is $x(t) = x_o = v_0 x and y is y(t) = y_0 + v_0$ and so on the solution is x,y,v_x,v_y with initial conditions to get a solution need the ode and the initial conditions
many problems (probbly most, cannot be solved by pencile and papper methods) so we need a starting genral ideas

1. Time or the independent verbal is discreet
2. The solution is iterative, involves a loop, continually approximates the solution starting form the initial conditions an example ode is
    1. $\frac{dy}{dt} = -\alpha y$ and $\alpha < 1$
    2. Time is broken into even intervals delta t
    3. The solution is sampled at each time point where $y_n = y(t_n), t_n = n\Delta t$
    4. N=0,1,2...n
    5. The ODE is now a difrence equation
    6. $\frac{\Delta y}{|}$ the idea is that it becomes
    7. This is the Euler update method #lookinto
    8. Y_1=y_0

9. The acurecy of the solution depends on Δ t which is chosen by the programmer smaller Δt leads to more accurate solutions but at the expense of of computation time
10. There is a trade of between the number of computations and and the acurecy
11. Taylor series expands a function into infinite powers and can be used to aproximate error it expands it in infinite powers of the independent variable
12. Y(tΔt)=y #lookinto how to expand into a Taylor series
13. The Taylor series is exact how to estimate a ODE with a. Taylor series #lookinto
14. If you knew y(t),dy/dt.. ie all the derivatives of the function then you know then you know y(t+Δt) how is this true?
15. the Euler method is called first order accurate it matches at the first order there are really two concepts of acurecy here, one decrease step size, and two match stick

3. with Euler method but solve a second order ode
    1. The trick is to turn a second order into two first order ode's
    2. Let's do the pendulum
    3. Mass m length L there's an angle phe is measured from the vertivle
    4. Let's think of the pendulum as having r and phe so now time to decompose the forces
    5. I need to derive the Rung kuta to get to the 4th order class I need to derive it
    6. The rk4 method and Euler methods and the leep frog are examples of fixed timsteps you declare a time step and you just role with it
    7. Ex: rk45 dop9853 adjust delta t to meet error tolerance criteria
    8. one method that we may be interested is block time stepping
    we can use a binomial expansion which is a Yalu or series
    7. Learn law of cos #lookinto
    8. Legerder polynomials #lookinto
    9. plot of the hilbertspace
    10. quadrapol tensor, whats the difrence between a tensor and a materix
    11. why is the fast multipol method fsater than the barns hut algorithm
    12. work on the pyflacon and stress test it

agama code

1. The current code uses random values for the galactic potential kind and inital possitions
    1. use the galactic potential in John's methods amd cpmvert tp lomd
    2. Try to model PAL 5 and NC6569.
        1. We will try to map their celestial coordinates to galactic-centric coordinates.
        1. John's method should do this
        2. the goal is to convert from spherical around the Earth to galactic Cartesian coordinates.
        3. she likly used astro Py (agama also provides functionality for this)
        4. We wanted a resource that contained information on how to do all of these conversions #deliverable
    3. stress test the notbook

2. **the Pyfalcon gravity module**
    1. returns a_i the acceleration for each star
    2. equaitons
        1. Φ_i and the potential for star I
        2. the potentual energy = $-G \sum i \frac{M_i}{r_i}$
        3. potentual energy is equal to
        4. Energy of the star =1/2v_i^2+phi_i
            1. based on gravity equations phi is always negtive and there for lookign for stars that have positive energy
        5. phi is negtive
        6. Center of mass = $\sum j \frac{r_j * m_j}{m}$
        7. aceleration total is = a from pyfalcon, and -nabla phi galixiy
3. An algorithm to compute the energy of the globular cluster.
    1. first compute center of mass velocity
    2. then comput V tilda_i=vi-v_cm
    3. then compute the energy using v tilda (Energy of the star =1/2v_i^2+phi_i)
    4. then id all stars when Etilda <0
    5. then repeat using onlyh the Id stars
    6. could we subtract the mean velocity ?
    7. average moment
    8. $\Phi = \frac{Gm}{|r-r'|}$
    9. th

terms

1. NFW potentual is a dark matter potentual method for the sourounding
2. energy budget of the universe
    1. how dose dark e
3. nutreno
    1. sub atomic particla with almost no mass
        1. (sun makes them)
4. quarks, 3 quarks make up a nutron or protons
5. leptons
6. gluons
    1. color charge quantom chromomatics
    2. exampsion rate of the universe is goverend by relitivity
    3. the dynamics of space time the sahe of space time is coppled to energy.
    4. if you have a sphwerical mass
    5. joes interpertaiton here
        1. we have equaiotns and those pridictions make

2. shan carol
    1. humans think in words and pictures, and those are analogies to the world but not perfect
    2. dose gravity make space larger ?
    3. difirentual geomitry
    4. shape of space time
    5. dark energy is added as a constant term
    6. the hot topic in cosmoligy is huble contension (the hubble rate dose not match the expansion rate of cosmic)

joans code

1. First, we import
2. set the galactic reference frame we will be using
3.

notes abotu quad trees

1. Note to Joe, from what I can see, quadtrees aren't centered on the center of mass of the cluster; instead, cells are created by subdividing evenly, and the center of mass is just the average center of mass of the particles in the cell.
2. Doxigen
3. potentule, gradent potentul, tidal tensor at a point and also obtaning the enclosed mass and density doxygen
   https://arxiv.org/pdf/1812.07313

hi

1.
2. phase space is position and velocity
    1. position and congigate
3. this cell establishes the galatic potentul
4. birds eye veiw
    1. galatic disk,
    2. dark matter halo
    3. bar
    4. cowardinate system (x,y,z)
    5. The disk potential is symmetric in the xy plane.
5. Hamotolen dynamcis
   1. Motivate Hamiltonian dynamics, show that Hamiltons equations give the equations of motion you are used to, i.e., F=ma
   2. gala solves using hamiltonian

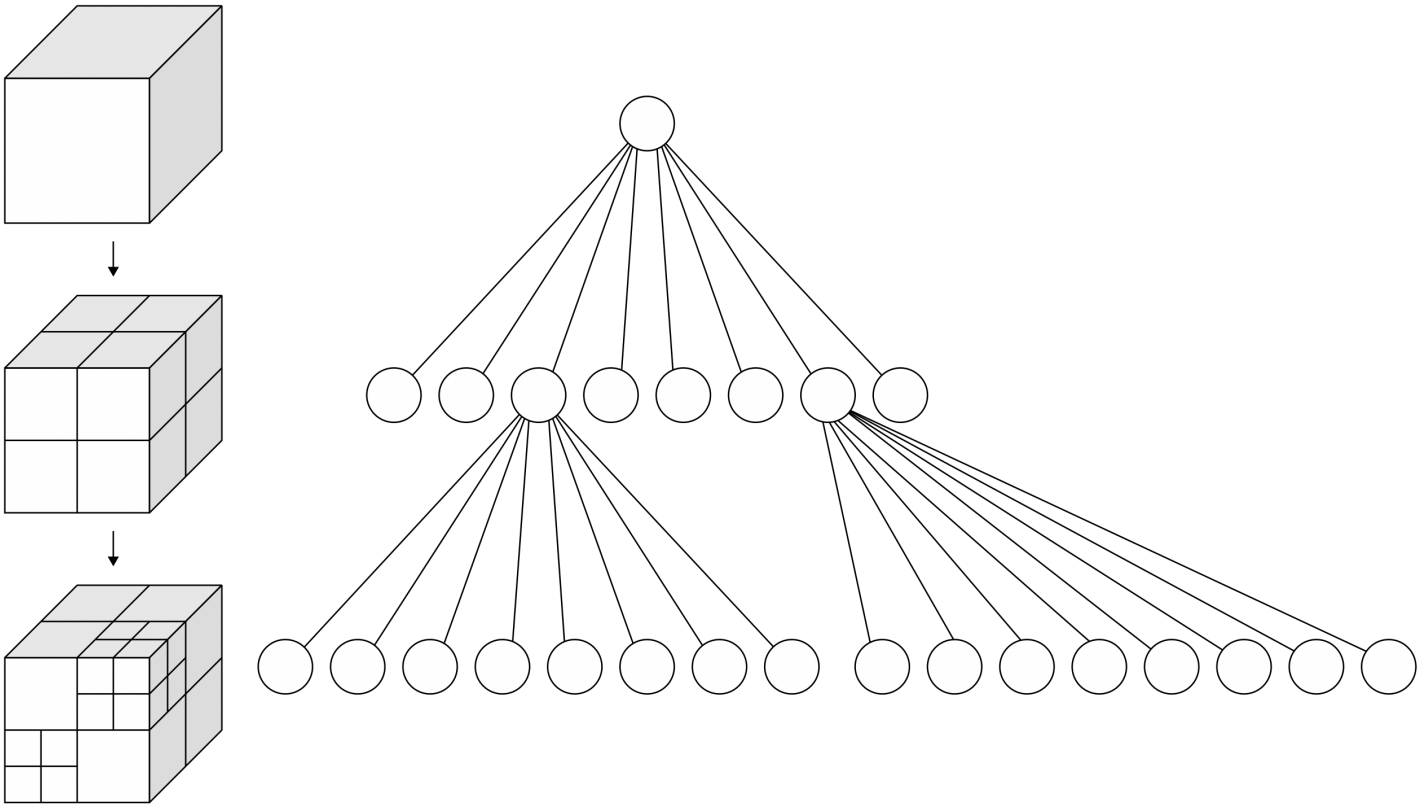
3. h=ke+pe
4. ke=ke (momentum and the position) its a function of
5. p is the congate momentum (so its not nesecarly m *v)*
6. *h=ke+pe*
1. *case gravity is near the surface of the earth*
2. *ke=1/2mv^2*
3. *p=mv v=p/m*
4. *ke=1/2*p^2/m
5. pe= mgy
6. h=1/2m^2/m+mgy
7. p=dp/dt=partical h/partical x
8. x=dx/dt=partical h/partical p
9. in our case x=y and p=p
10. dp/dt= partical h/partical y=-mg
11. f=ma
12. =partical h/[artoca; y=-mg
13. p=mv
14. dp/dtmdv/dt
15. mdv/dt=-mg
16. ma=-mg
17. dydt=partical h/particalp=partical/particalp (1/2p^2/m)=p/m
18. dy/dt=v
19. symplectic gemotry

https://arxiv.org/abs/1410.1861 #lookinto read
https://arxiv.org/abs/2408.01496 also read

two papers on the particle spray method: 1) how many simulations did they do, how many particles, what galactic potentia, what n-body code
what is the particle mass
do they expect the method to work for orbits that come close to the galactic center look for limitations

barns hut tree

1. how it works
2. we break up stars into cells and use the multipole expansion to estimate the distance between them
3. so for a star m_i we caluate the distance between that star and the center of mass
4. the second part is a correcting quantity
5. What's the difference in accuracy between quadripole and monopol versions?
6. what dose transpose mean with matrixes ? #lookinto and learn tensors
7. the algorithm requires partinitaning of the simulation into sub cubes (this is the tree part)

8. 
9. this is an octree vizulization
10. now talking about θ
    1. theta is the veiwing angle
    2. is it faster to pree compute or is it faster
11. partical class
    1. contains the velocity the position and the mass
    2. Object orientated programing
12. you create objects that have their own methods and atributes
13. a method is a function and an attribute is a variable
14. Talking about octree
    1. we start by determining the distance between all points, this is used to create the bounding box of all points
    2. then we create the box from the max of their values,
    3. we then add padding $\epslon$
    4. then you set half width with L/2
    5. and center is (L/2,L/2,L/2)
    6. then we need to have an object called node initilizized with center and half width
    7. you have a method called insert wch ditermins which particles are with in the node
    8. if its in the node then you have to count the number of particles in the node
    9. if the number of nodes is greater than one we subdevide
    10. we defind quarter width =half width devided by 2
    11. it would have center cx-qw, cy-qw,
    12. you create childe 0's center and then you call node childe 0 center and then node insert particles

13. child 1's center is equal to --

potentule

1. phe is the gravitatonal poptentual=U/m
2. g is the aceleration at point r
3. for a poiny mas g(r)=-nabla phi
4. fot a poiny mas phi=-gm/r
5. phi=ig initgral of row(r)/r-ri
6. potentual
7. potenrual oclass
    1. phi, -nabla phi,delta phi/partical)
    2. binomial aproximation
    3. (1+x)^alpha =1+ax

to do

1. get the location in sky coord for pal5
    1. and learn how to convert to
    2. (use bombgart)
    3. this is the informaiton to learn

```
GC_6569bt = coord.SkyCoord(ra = 229.022*u.degree, dec = -0.111*u. degree,

distance=(20833.33)*u.pc,

pm_ra_cosdec= -2.730*u.mas/u.yr,

pm_dec= -2.654*u.mas/u.yr,

radial_velocity= -58.4*u.km/u.s)

GC_6569b_rep = GC_6569bt.transform_to(coord. Galactocentric). data
```

find infromation at
Primary Sources:

- **Gaia Data Releases** (EDR3/DR3) - Best for precise astrometry, proper motions, and parallax distances
- **SIMBAD Astronomical Database** - Comprehensive object database with compiled measurements
- **NED (NASA Extragalactic Database)** - Though primarily for extragalactic objects, includes some galactic clusters
- **Harris Catalog of Globular Clusters** - The standard reference for globular cluster parameters

pointers

1. passing by refrence
2. pointers are replaced if you have garabage colectors
3. move somantics
4. I need to learn how stackes vs heap memory works
   learn the difrenc ebetween headders and cpp files
   even if the headder file is only one line of code

learn documentation
the goal is understandibility
and longevity

I need to learn defensive programing
1 error checking at every turn
input validaiton unvalid states
I need tp program in checks and balances to help their understanding and provent issues

program by contract

Learn pre and post conditions.
Need to talk about documentation.
Class invariants.
Learn how inheritance works in C++.
Difference between protected and private.
1. public, private, protected
1. public means any class anywhere can access that data.
2. private means only itself can access.
3. and protected means only itself and anything that can inherit.
4. is a full vector better
5. learn list and matrixes
6. learn how to use entity inharatence tree
note how my profesors playes elden ring and night reign
hates the ancient dragon

globular clusters

1. Getting a gala pipeline working
2. At the top, you choose the globular cluster coordinates, and everything else runs after that
3. run it with agama (does gala have the chin particle spray method?)
4. taker joans code and make it do pal 5
5. then make a pipeline where you input the globular cluster and mass
6. you also input the timestep, and then you run the code.
7. and you want to update from fardell to chen

1. study how the distribution of the mock streems are initilized (can we make it a difrent paramater ?)
2. in the one below the picture it tells gala to initgrate in a rotating frame
3. the bar rotates at some omega we need to transofrm at the end to set all the data to the static frame

Name	α [deg]	δ [deg]	[masyr−1]	[masyr−1]	corrμ	[mas]	_R_0 [′]	_N_memb
Pal 5	229.019	−0.121	-2.730	-2.654	0.00	.048	3.17	233

mass 1.3*10^4

gc-stream-toolkit

```
gc-stream-toolkit/
├── gcstream/                    # Main package (import gcstream)
│   ├── __init__.py             # from gcstream import setup_environment
│   ├── setup.py                # setup_environment() function
│   ├── cluster.py              # Cluster class
│   ├── potential.py            # GalacticPotential class
│   ├── generator.py            # StreamGenerator class
│   ├── integrators.py          # Built-in integrator functions
│   ├── coordinates.py          # Coordinate transformation utilities
│   ├── visualization.py        # Plotting functions
│   └── utils.py                # Helper functions
├── examples/                    # Tutorial notebooks
│   ├── 01_basic_usage.ipynb    # Getting started
│   ├── 02_pal5_recreation.ipynb # Your Pal 5 work
│   └── 03_custom_integrators.ipynb
├── data/                       # Cluster catalogs, reference data
│   ├── cluster_catalog.csv     # Standard GC parameters
│   └── potential_presets.yaml  # Common galactic potentials
├── tests/                      # Unit tests
│   ├── test_cluster.py
│   ├── test_generator.py
│   └── test_integrators.py
├── docs/                       # Documentation
│   ├── README.md
│   └── api_reference.md
├── requirements.txt            # Dependencies
├── setup.py                    # Package installation
```

```
├── .gitignore                  # Python + Jupyter gitignore
└── LICENSE                     # Research-friendly license
```

next monday

1. joe created a fully nbldy simulation using flacon
2. joe's data looks very split, it shreds the cluster
3. Nbody6tt which I shoudl install ?
4. pyfalcone
5. getting stelar evolution working would be a big help
6. what the nootbook ahs
    1. build a pipline
        1. a configuration file
        2. code (never touch it)
        3. then a not book interface
        4. then post processing files (that allow you to process the code)
        5. then compair out puts with one another (this is a good way to check if your right)
    2. style, we need comments, propper python style docstrings and read me's
    3. sample a king modle can gala do this use maby galpy?
        1. so we can compare my code to your results
           understand the coordinate trandofmraitons
        2. and code your own funcitons to do it to make sure they match astropy
    4. it would be intresting to compare fardell streams to chen streams

new day notes

1. side projects to each person
2. thea side project
    1. joe said it would be on a sheet for students
    2. paralax
    3. redshift vecloity in propper motins ra and dec radial velocity
    4. learning how to use latex
3. thea side project order of magnitude estimations
4. learn about stelar evolution
    1. have a book that codes stelar evolution its half a chapter how do they work and make a notebook that simulates them
    2.

talking about nodes and trees

talking about compisation
5. they represent different versions

6. compisition vs inharitance
7. is a relationship
center cube

```
#cube length equation

delta x= max(z)-min(z)
delta y= max(z)-min(z)
delta z= max(z)-min(z)

cube length = max(delta x,delta y,delta z)+ pading

#cube center equation
cube center = (
        x= xmax-xmin/2,
        y= ymax-ymin/2,
        z= zmax-zmin/2,
        )
```

oct tree class

what dose sympletic mean how is kick drift second order acurate #lookinto
how to understand higher sumpletic

get falcon running in C++ on my computer
try to compare to direct Nbody simulation

what is jax its a jit compiled
version of gala in Jax galax
woudl like a way to track the particles at birth wihth phi gravity phi globular cluster, and the tidal tensor values
numarical methods in astrphyics