NEMO:

a case study for AMSC 664

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URL: http://www.astro.umd.edu/nemo

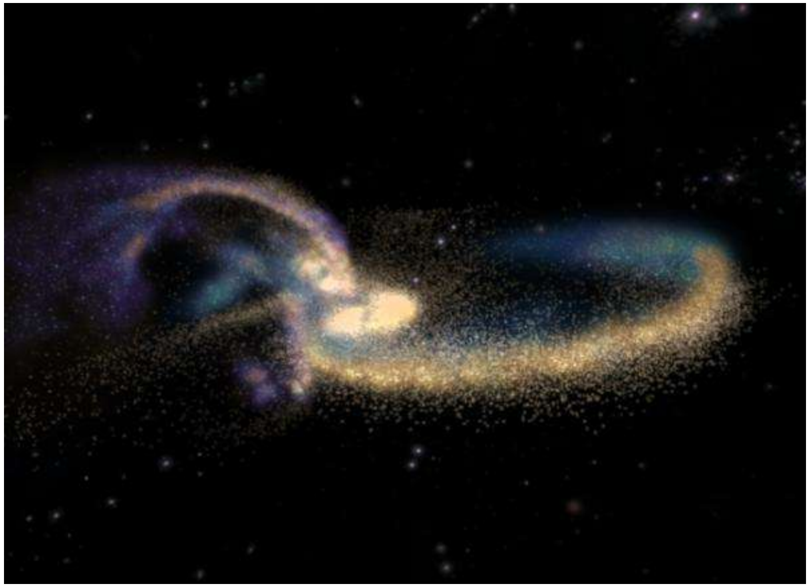
URL: http://www.manybody.org

Version: 10-apr-2004

Collional and Collisionless Dynamics

STARLAB

NEMO



NEMO

- Observational Astronomy has many software packages (AIPS, IRAF, Gipsy, Figaro, ...)
  - Each telescope has specific calibration needs
  - Image processing is nearly always the same
  - A data interchange standard (FITS) emerged
  - The wheel was re-invented many times
  - Group Effort
- Theoretical Astronomy has not! (1986)
  - Individual Effort (still)
  - but: Virtual Observatory (2000 decedal survey)

Design

- *N-body integrator(s) with* many small tools, each performing a small well defined task
  - ? modern approach → python-like scripting ?
  - NEMO vs. tipsy approach
- Easy to use
- Easy to extend
  - Add your own code
  - Add foreign code

Design (cont'd)

- Uniform (command line) user interface
  - Good help facilities
  - Graphics vs. Command Line
- Portable binary (hierarchical) dataformat
  - endianism, floating point accuracy
  - Unix-like use of pipes
- Graphics: YAPP
- Dynamic function use (.so, .dll)

User Interface

- main(argc,argv) → nemo_main(void)
  - nemomain.c defines main()
- User interface:

```
char *defv[] = {
 “out=???\n      input file”,
 “nbody=100\n    particles”,
 “VERSION=1.0\n  9-apr-2004 PJT”,
  NULL};
```

- Program vs. System keywords

User Interface (cont'd)

- System keywords
  - help=
    - Internal help vs. external (man pages, html)
  - debug=

    -
      ```
      dprintf(2,”N=%d Level=d Radius=%g\n”,n,l,r);
      ```
  - error=

    -
      ```
      error(“%d too large (MAXFOO=%d)”,n,MAXFOO);
      ```
  - yapp=
    - Value depends on the library used at installation

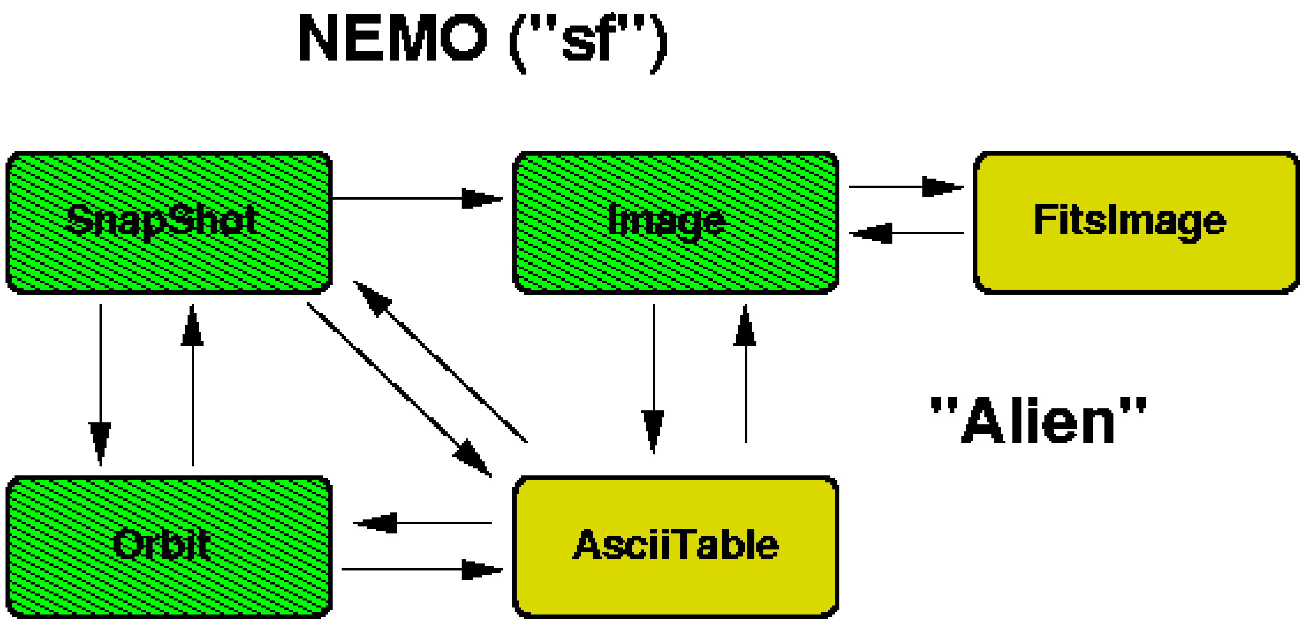
User Interface (cont'd)

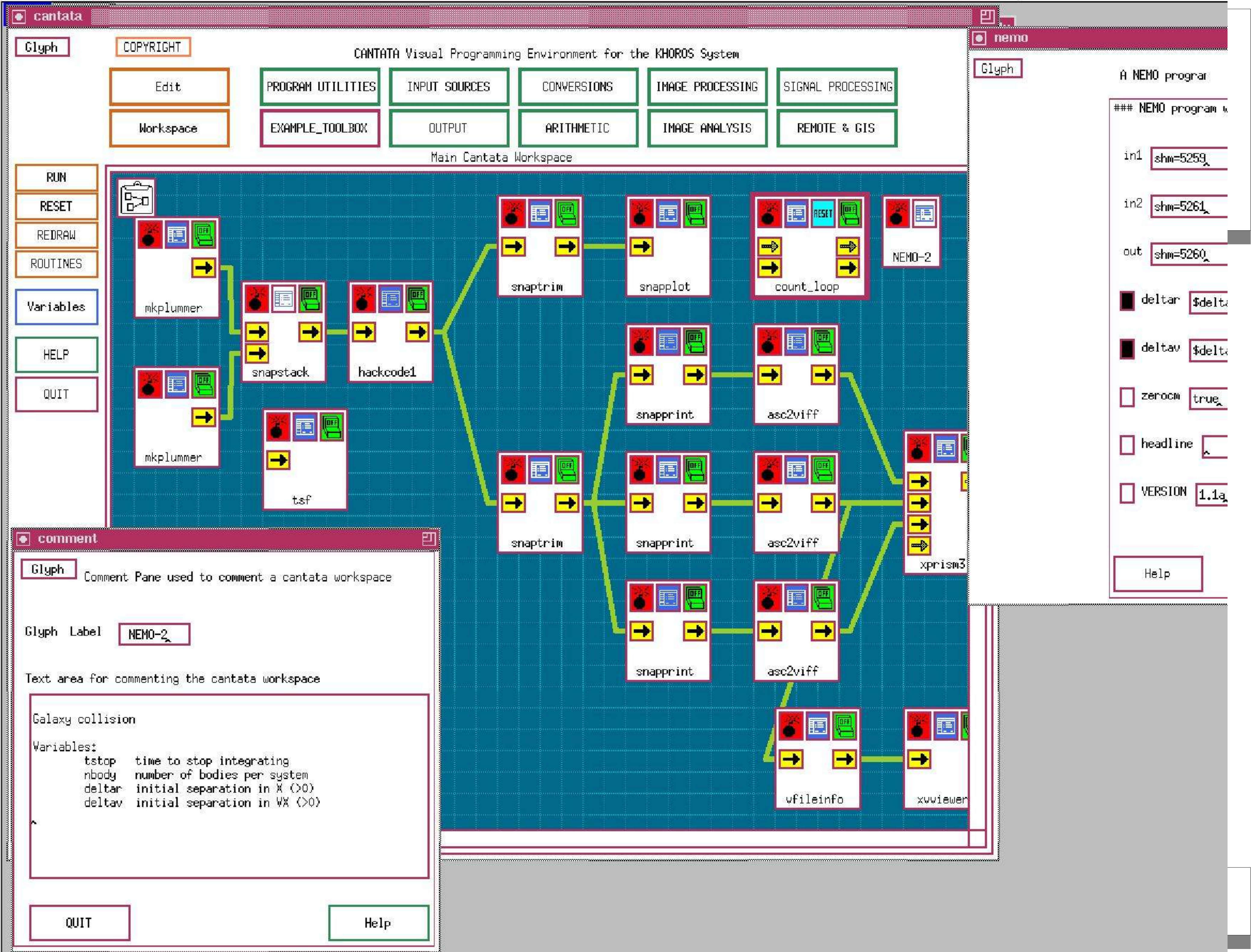
- Help
  - Internal help
    - (help=) comes with every NEMO executable
  - External help:
    - Standard unix man pages (and html formatted)
      - Man, tkman, xman, gman
    - Users and Programmers Guide
    - FAQ

File Format

- Binary Structured Files
  - Sequency of tagged items
    - Tag : name, type, dimension
  - Hierarchical
  - Always written in native endianism
  - Portable (detect endianism)
  - Transparently detect pipes (`fname=-`)
- User tools: tsf, rsf, csf, qsf

NEMO file formats





CANTATA Visual Programming Environment for the KHOROS System

Main Cantata Workspace

Comment Pane used to comment a cantata workspace

Glyph Label NEMO-2

Text area for commenting the cantata workspace

```
Galaxy collision

Variables:
        tstop   time to stop integrating
        nbody   number of bodies per system
        deltar  initial separation in X (>0)
        deltav  initial separation in VX (>0)
```

A NEMO progra

NEMO program w

in1 shm=5259

in2 shm=5261

out shm=5260

■ deltar $delt

■ deltav $delt

□ zerocm true

□ headline

□ VERSION 1.1a

Graphics: YAPP

- Yet Another Plotting Package
  - Define a simple API that can be implemented by a number of popular graphics packages
    - pgplot (Caltech Astronomy)
    - plplot (sourceforge)
    - Mongo ($$$)
    - SM ($$$)
    - PS (nemo)
    - OpenGL
    - Null (nemo)

Dyamics Functions

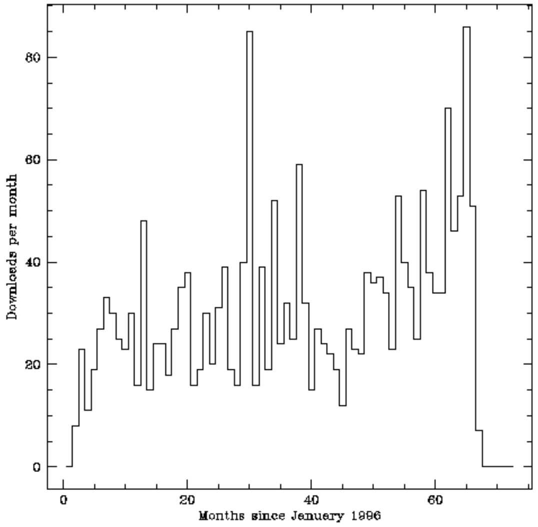
- Interface to an efficient way to use dynamics functions (now implemented via dlopen(3))
  - Snapshots: *bodytrans* variables (e.g. xvar=x/z or evar='m/sqrt(x*x+y*y)'
  - Orbits: *potential* functions, so tools do not have to be recompiled for new potential. Uniform interface using potname=, potpars=, potfile= (also used in some Nbody integrators now)
  - Tables: *fitting* functions, only used in non-linear least squared fitting program (tabnllsqfit)

Building NEMO

- Autoconf + hierarchical makefile's
  - Single library (libnemo.a)
  - Lots of optional Alien packages in NEMOLIB
    - HDF, cfitsio, pgplot, gsl, vogl,
- Testfile's for regression testing
  - Not hierarchical, a script hunts for them and runs “make -f Testfile all”
  - Output can be compared to archived version
- NEMODAT contains
  - standard datasets
  - Benchmark data

NEMO

- A toolkit of libaries and tools (programs)
- Scripts provide the glue to do simulations and analysis
- Portable structured (binary) files (snapshot, orbit, image, table)
- Initial work by Barnes, Hut & Teuben (1986) [Teuben 1995]
- SRC: source: 193 KLOC, man: 33 KLOC files: 936
- USR: source: 860 KLOC, files: 4141
- Unix makefiles, autoconf, CVS
- Mostly C, and some C++ and Fortran
- Many user contributions
- Wishlist.....



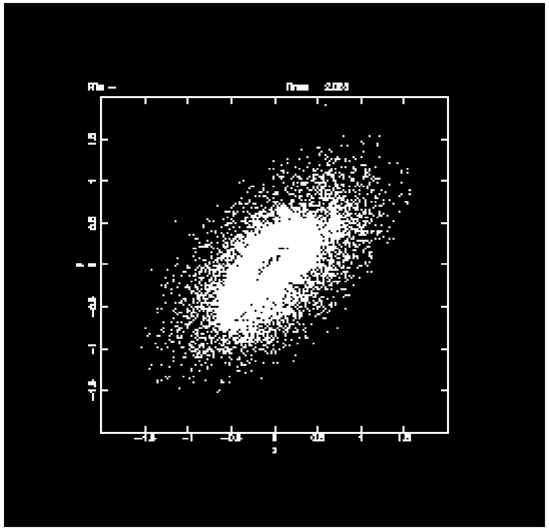
http://www.astro.umd.edu/nemo Info and Download

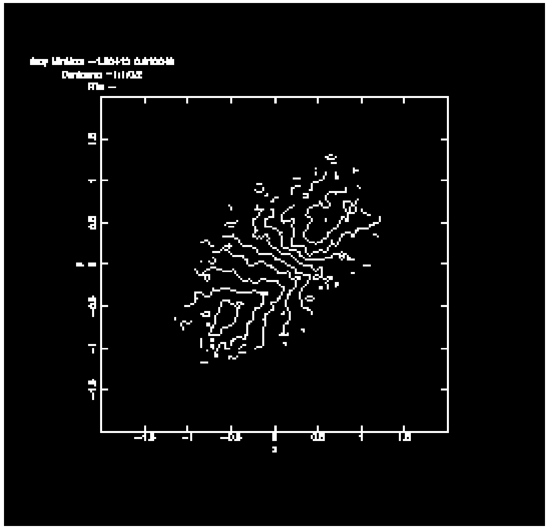
NEMO: some public codes

- Nbody* (Aarseth) [usr]
- Ptreecode (Dubinski)
- PMCode (Klypkin)
- Gadget (Springel)
- AP3M/hydra (Couchman)
- Galaxy (Sellwood)[usr]
- Treecode (Hernquist)[usr]
- Treecode1 (Barnes)[usr]
- Tree++ (Makino)[usr]
- Vtc (Kawaii)[usr]
- Scfm (Hernquist)[usr]
- Multicode (Barnes)[usr]
- Flowcode (Teuben)[usr]
- Superbox (Richardson)
- YANC (Dehnen)[usr]
- gyrfalcON

NEMO example

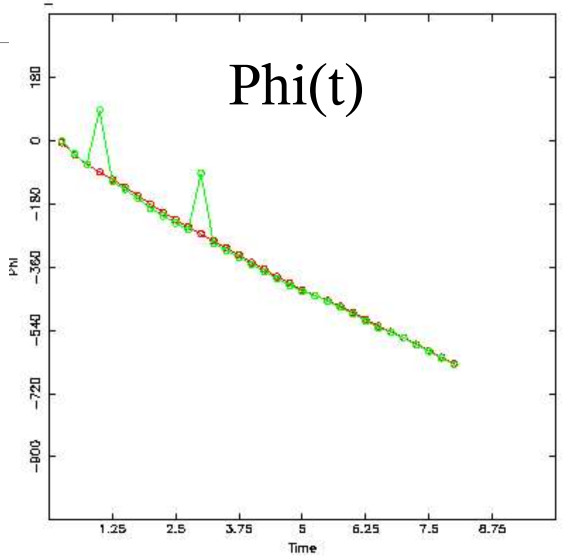
Evolved exponential disk, rotated and inclined velocity field

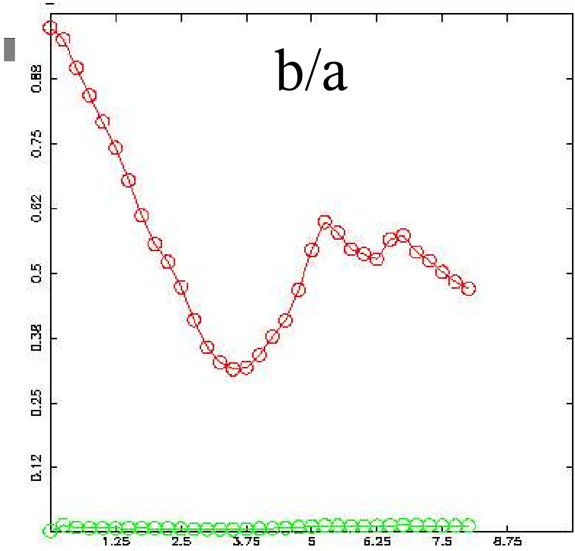


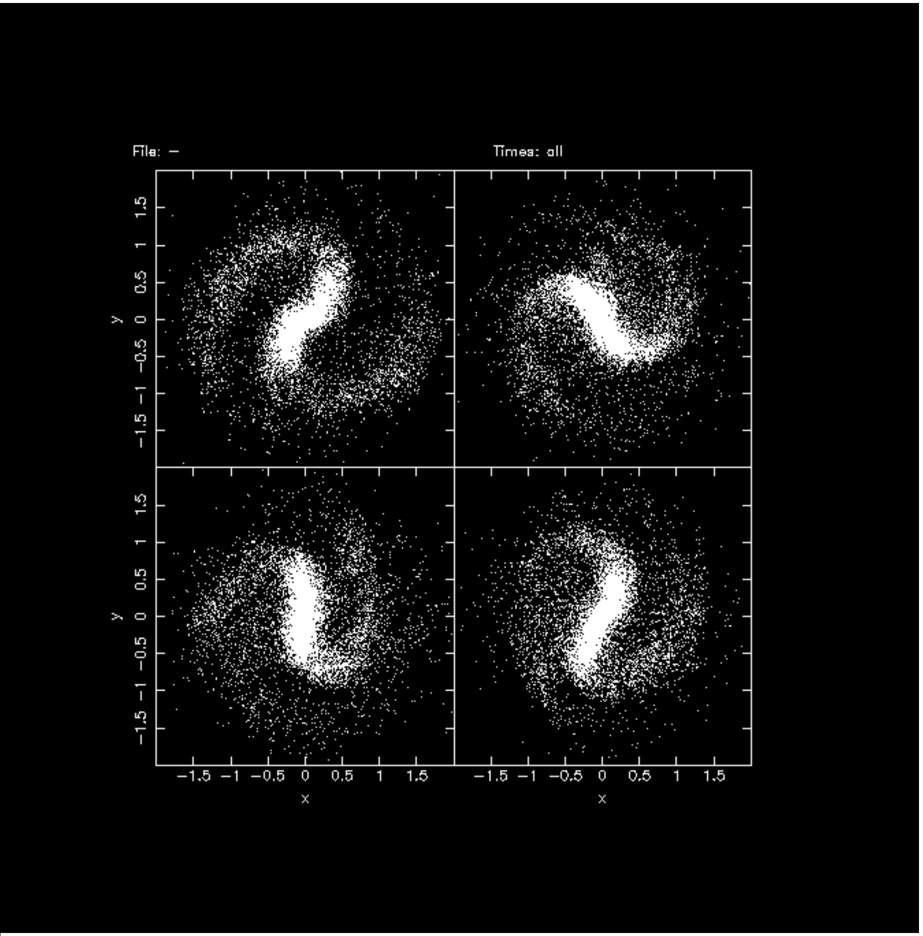


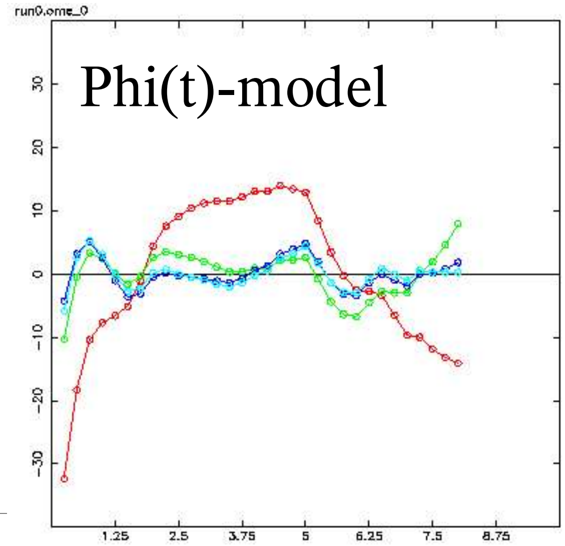
```
mkexpdisk  -   20000 rcut=2 | hackcode1  -   disk4.out tstop=4
snaprotate disk4.out  -   60,45 xz | \
   snapplot  -   times=2                                  (left panel)
snaprotate disk4.out -   60,45 xz   | \
   snapgrid  -   -   zvar=vz moment=-1 times=2 | \
   ccdplot  -   contour=-1:1:0.2 blankval=0             (right panel)
```

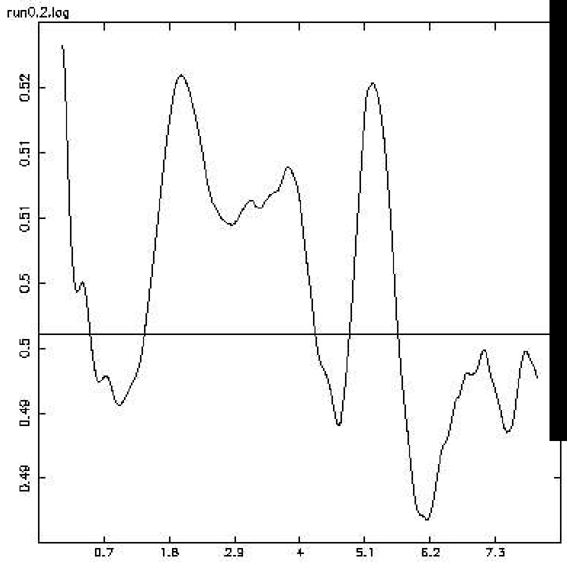
Optimal N-body softening: Seed=1,2,3,4


Phi(t)


b/a




Phi(t)-model

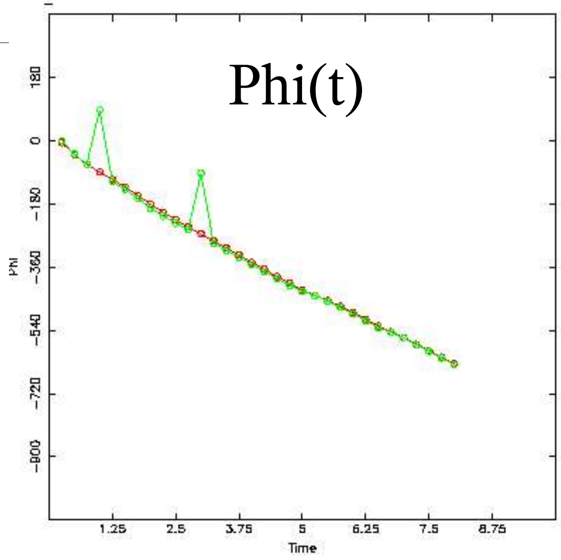


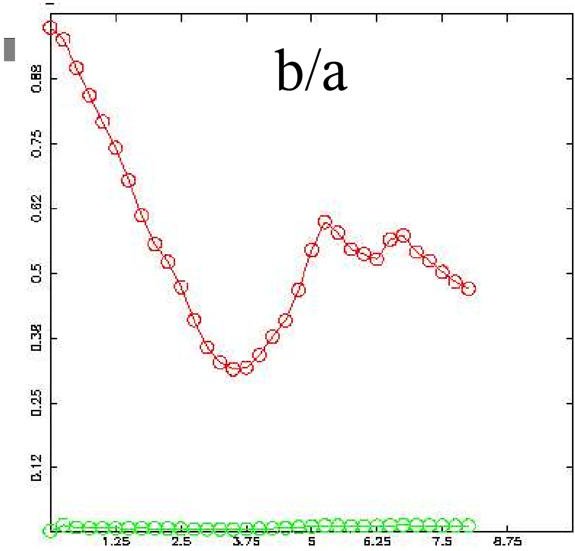
Dehnen & Teuben, 2004

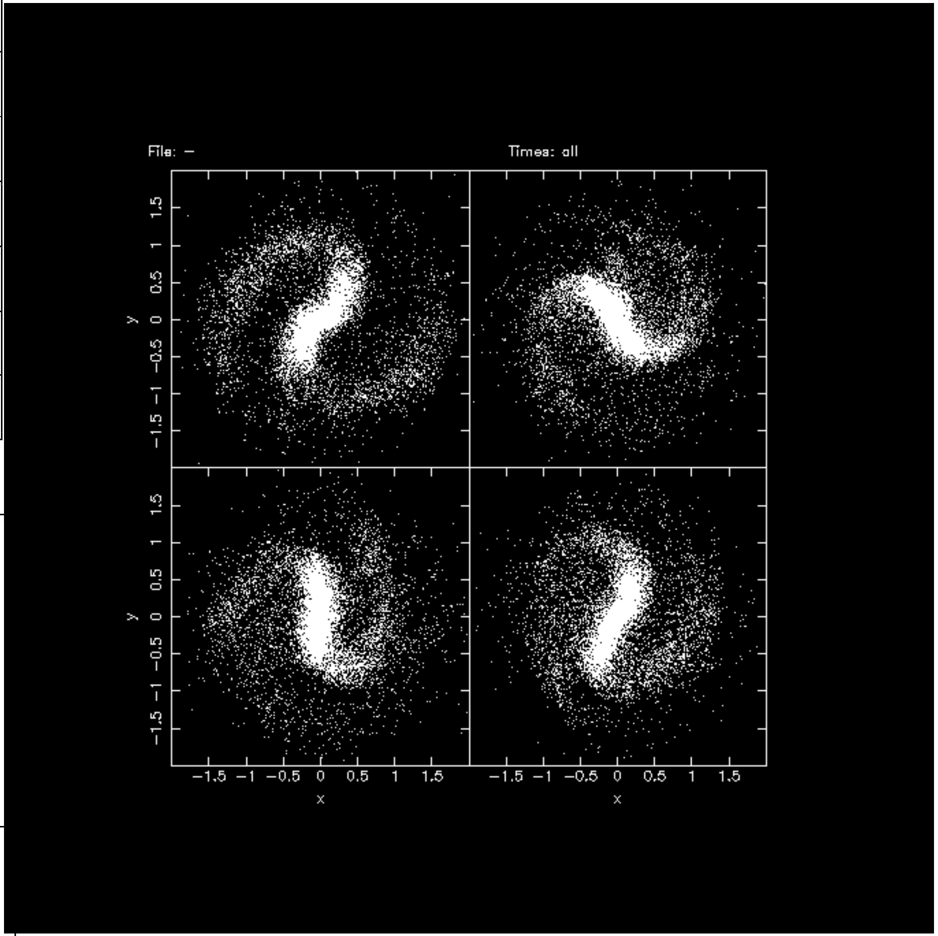
Time

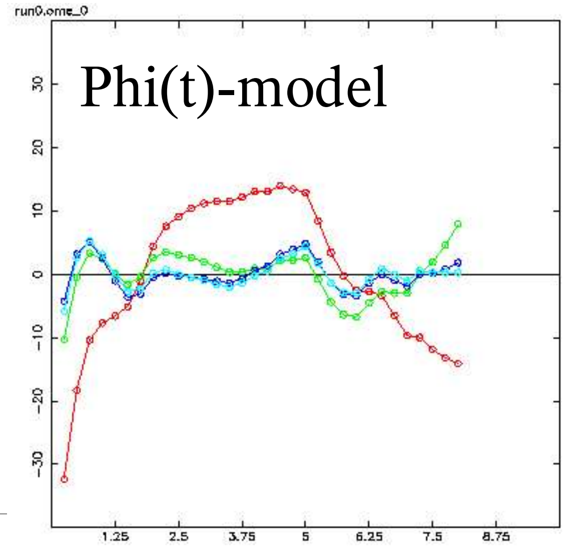
```
#! /bin/csh -f
#

mkexpdisk out=$run.ini nbody=$nbody Qtoomre=$Qtoomre seed=$seed rcut=$rcut tab=t \
        headline="$*" time=0 > $run.tab

YancNemo in=$run.ini out=$run.snp \
    eps=$eps theta=$theta kernel=$kernel \
    tstop=$tstop step=$step hmin=$hmin give_pot=1 give_rho=1 > $run.yanc

set times=0:${tstop}:${step}
set weight=("-phi*phi*phi")

#   loop over all times requested
rm -f $run.psi
foreach t (`nemoinp $times`)
    rm -f $run.snp.tmp
#   extract time & sort bodies by potential
    snaptrim $run.snp - times=$t |\
     snapsort - - phi |\
     snapmask - $run.snp.tmp 0:$nfract
#   align & get phase angles
    snaprect $run.snp.tmp . weigth="$weight" > $run.tmp1
    set ex=(`grep e_x $run.tmp1 | awk -F: '{print $2}'`)
    if ($#ex != 6) continue
#   also obtain axis ration of moments of inertia
    snapinert $run.snp.tmp - weight="$weight" tab=t > $run.tmp2
    set si=(`cat $run.tmp2`)
#   output: time psi Ixx Iyy Izz
    echo $t $ex[6] $si[11] $si[12] $si[13] >> $run.psi
end
```

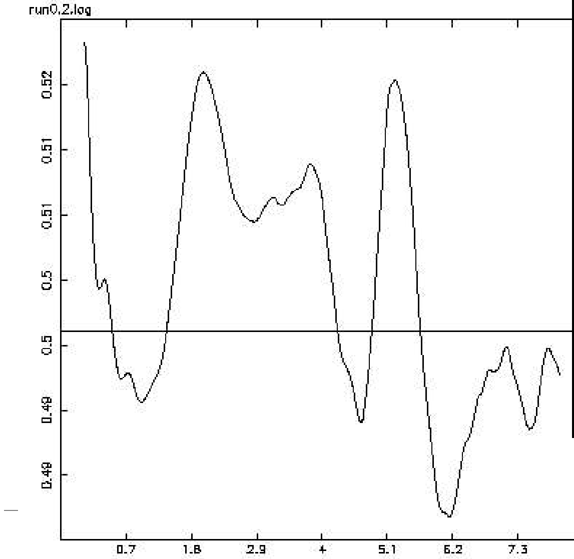
Optimal N-body softening: Seed=1,2,3,4


Phi(t)


b/a



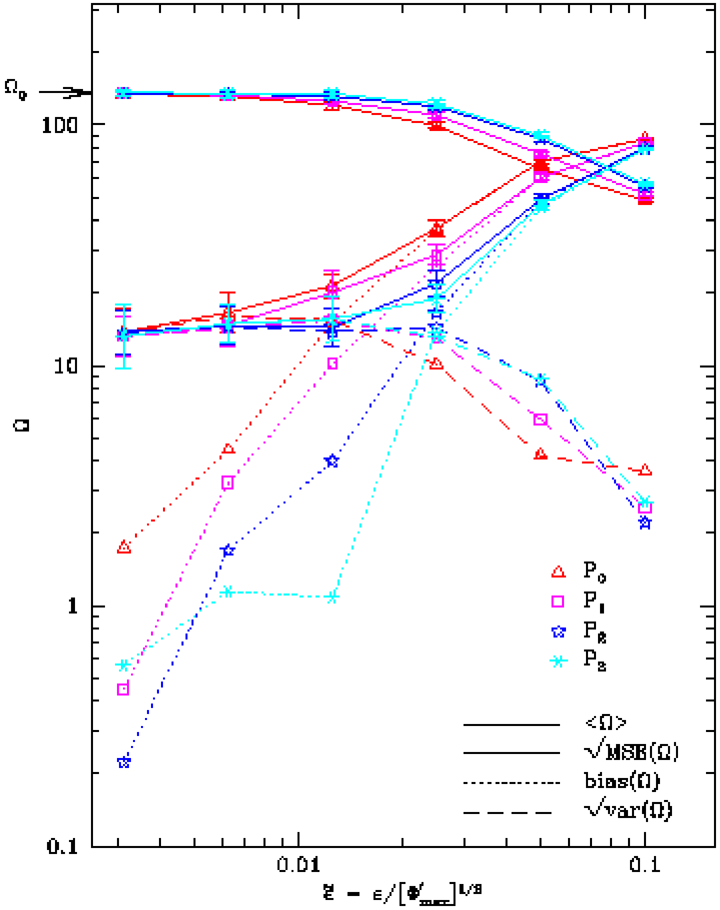

Phi(t)-model

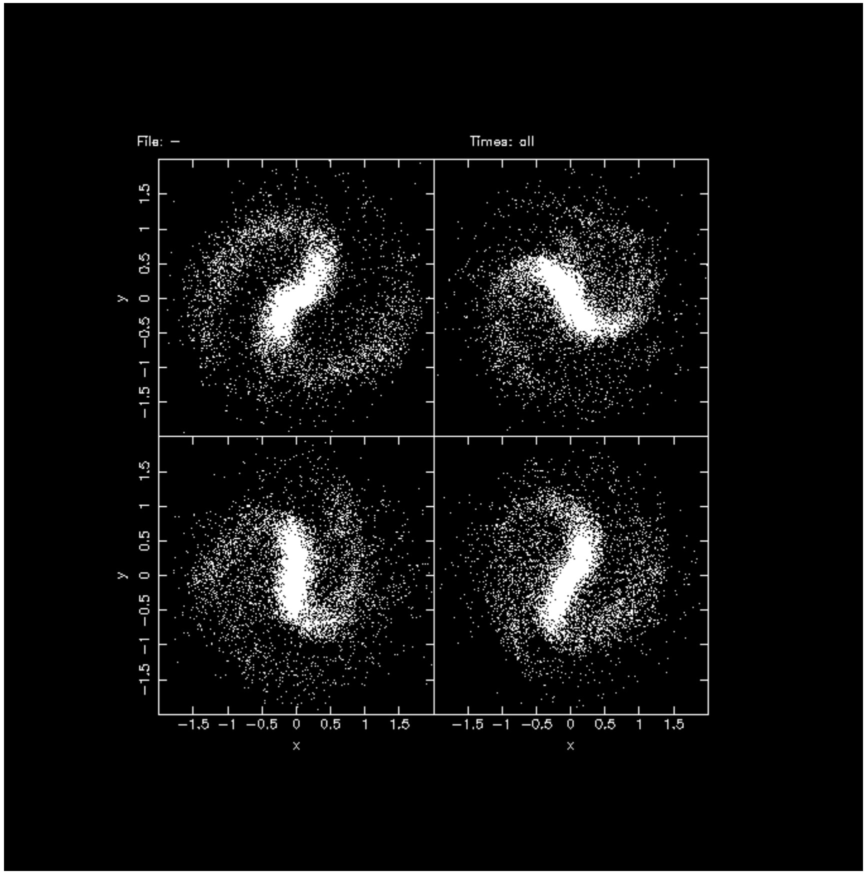


Time

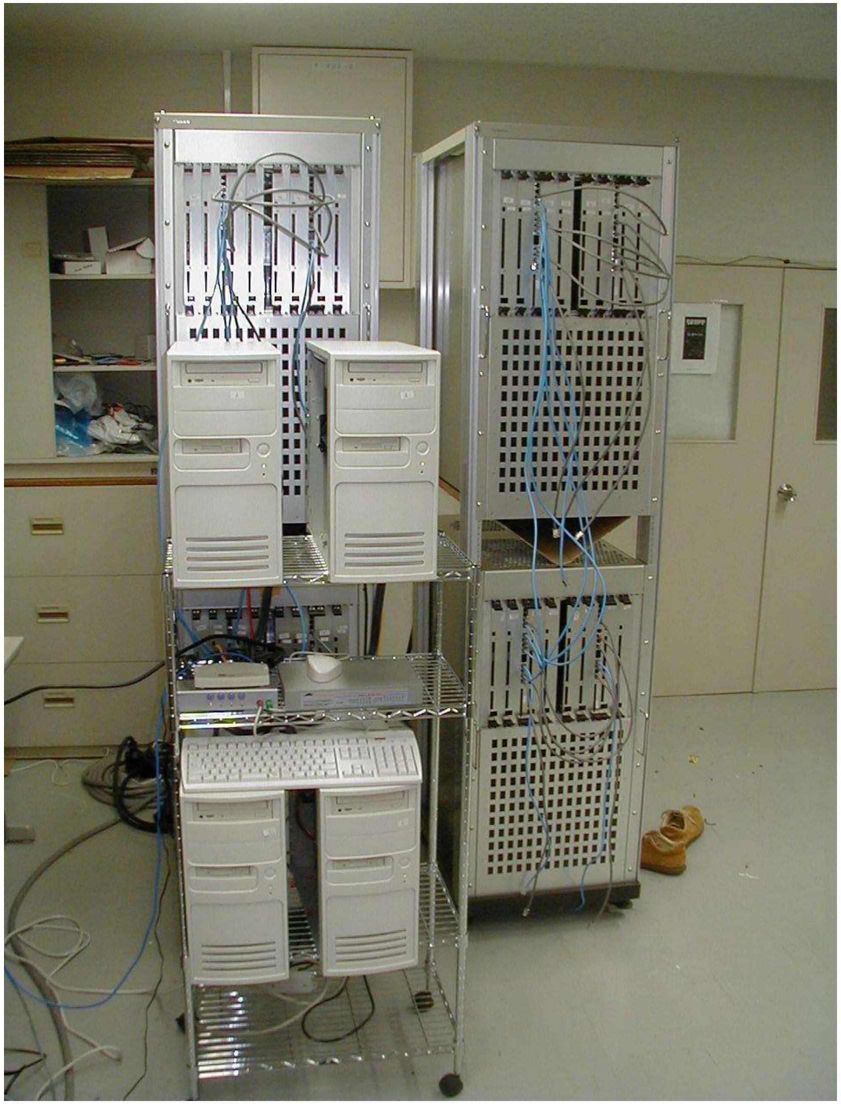
Dehnen & Teuben, 2004

Optimal N-body softening



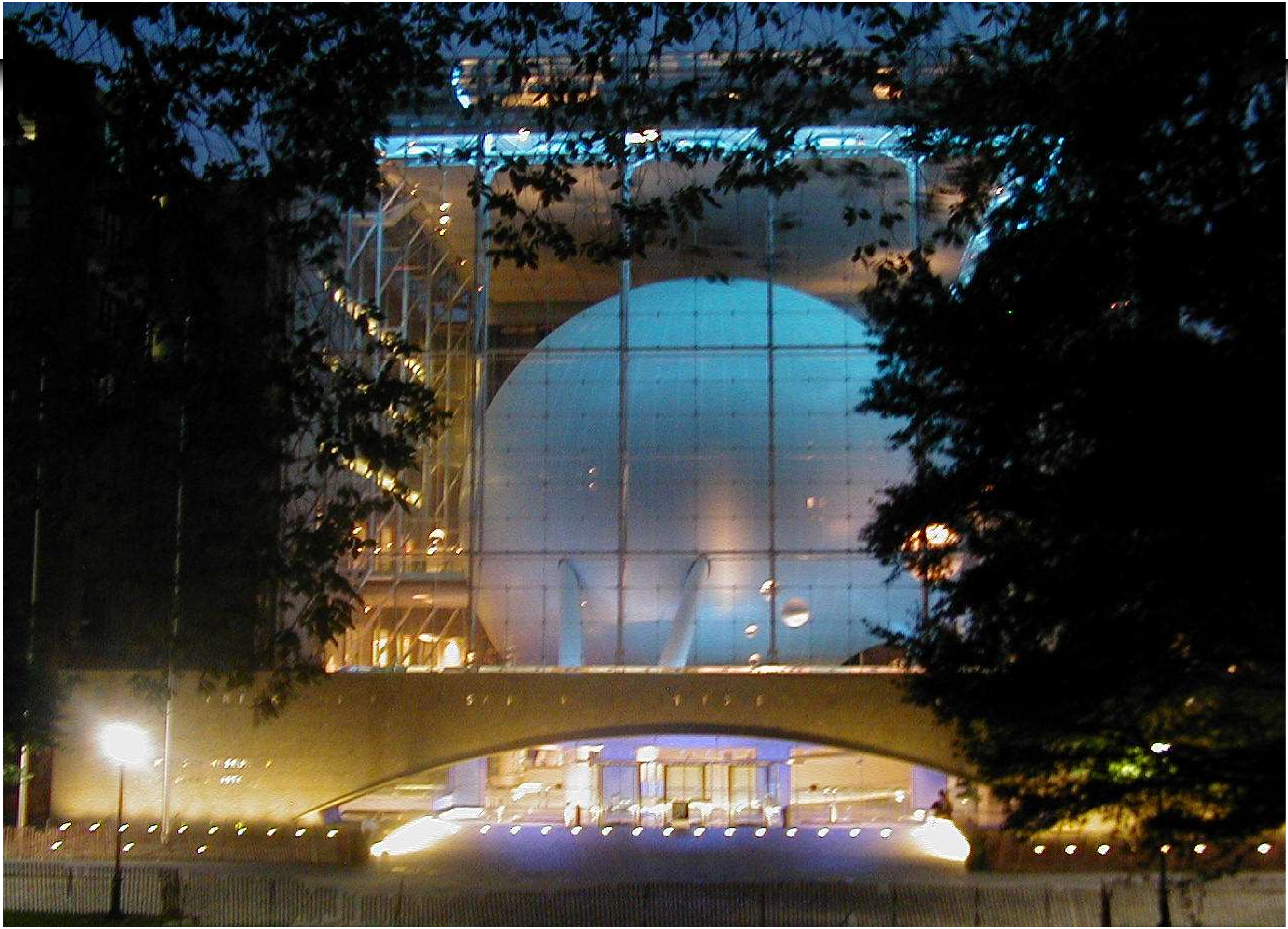


GRAPE-6 and baby-GRAPE-6



Tflops and Tbytes

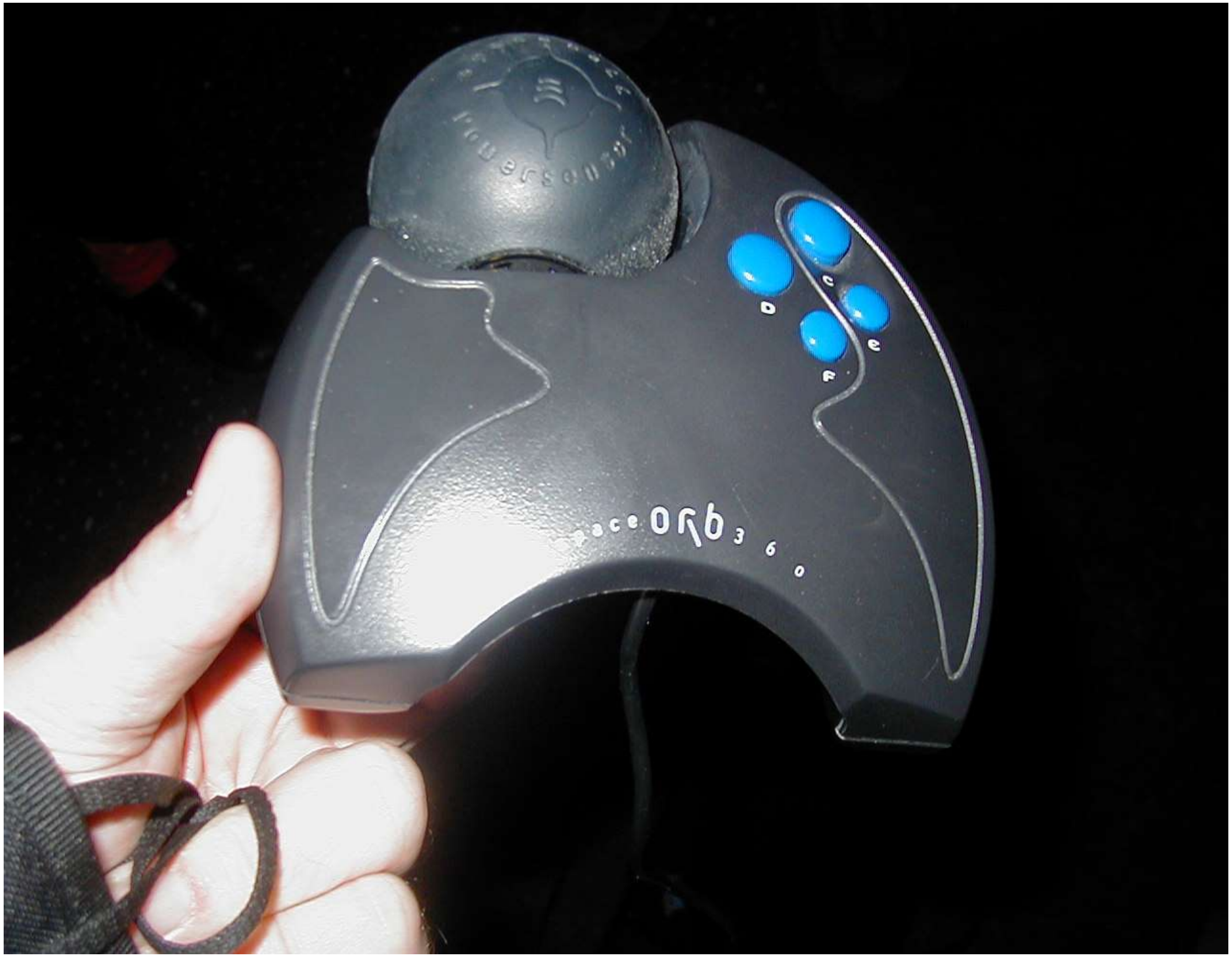
Hayden Planetarium



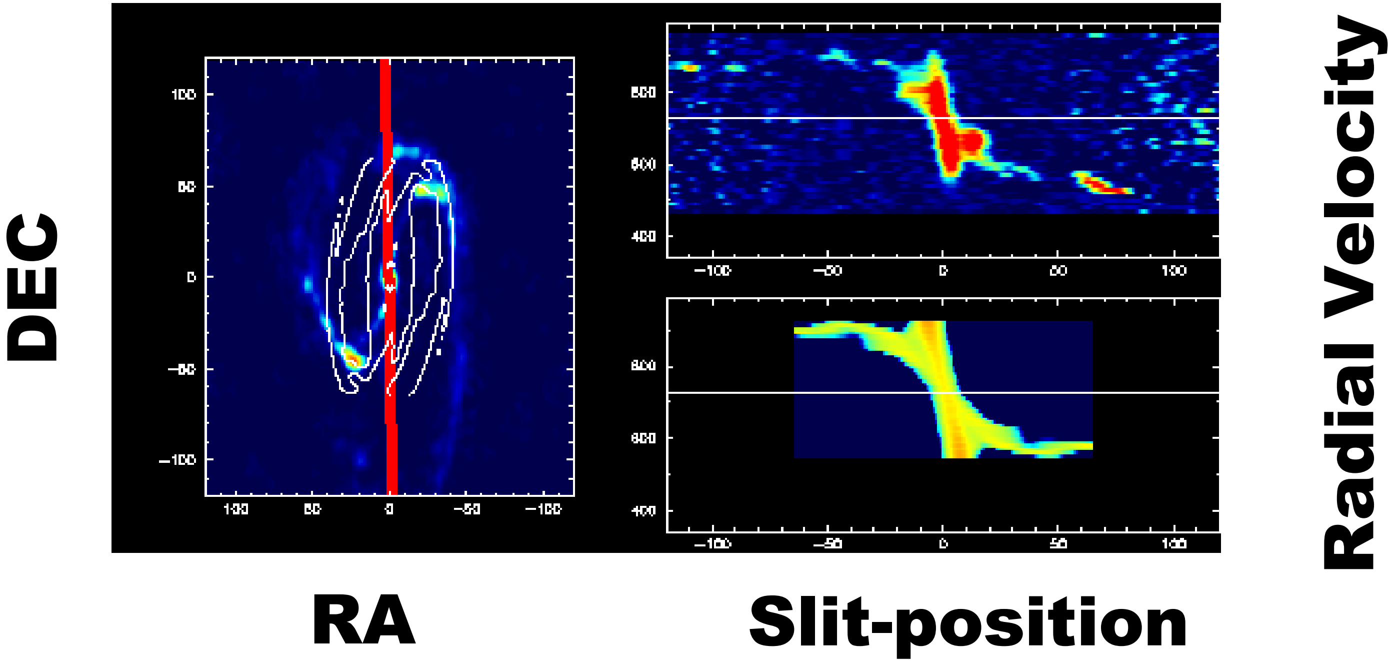
Setup in the Hayden Planetarium

Dark time in the Dome

SpaceOrb motion control



Galaxy Modeling



➔ GIPSY, AIPS/AIPS++, NEMO, karma