

NBODY6 Input File

1 20.0

1000 1 5 50000 95 1

0.02 0.02 0.3 2.0 10.0 100.0 2.0D-05 1.0 0.5

0 0 0 0 1 0 1 0 0 0

0 0 0 1 1 1 0 0 0 0

1 0 2 0 0 2 0 0 0 2

0 0 0 0 0 0 0 0 0 3

0 0 0 0 0 0 0 0 0 0

1.0D-05 1.0D-04 0.2 1.0 1.0D-06 0.001

2.3 10.0 0.2 0 0 0.02 0

0.5 0 0 0 0.125

KSTART TCOMP

N NFIX NCRIT NRAND NNBMAX NRUN

ETAI ETAR RS0 DTADJ DELTAT TCRIT QE RBAR ZMBAR

OPTIONS (50)

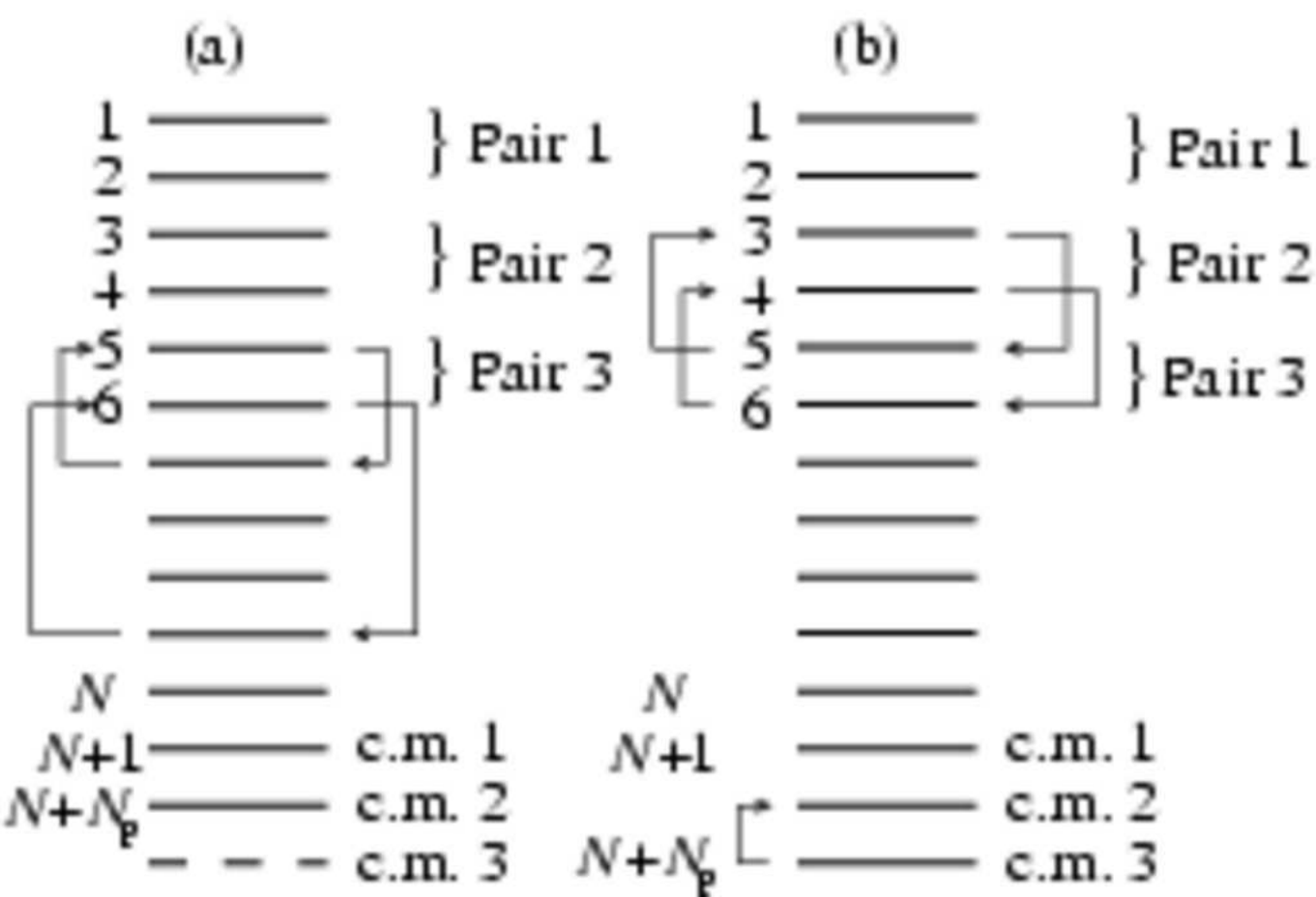
DTMIN RMIN ETAU ECLOSE GMIN GMAX

ALPHAS BODY1 BODYN NBIN0 NHI0 ZMET EPOCH0 DTPLOT

Q 0 0 0 SMAX

Essential Input Parameters

| | |
|-----------------------|---|
| Particle numbers | $N, n_{\max}, N_{\text{crit}}$ |
| Integration variables | $\eta_{\text{I}}, \eta_{\text{R}}, S_0, \Delta T, T_{\text{crit}}, Q_{\text{E}}, R_{\text{pc}}, \bar{m}$ |
| Optional procedures | consult list of 50 choices, in define.f |
| KS parameters | $\Delta t_{\text{cl}}, R_{\text{cl}}, \eta_{\text{U}}, \gamma_{\text{min}}$ |
| IMF | $\alpha, m_1, m_N, N_{\text{b}}, \#20$ |
| Virial theorem | $Q_{\text{V}} = 0.5$ for equilibrium |
| Primordial binaries | $a_{\max}, e_0, m_1/m_2, a_{\min}, \#20$ |
| Numerical examples | $N = 1000, n_{\max} = 95, \eta_{\text{I}} = 0.02, \eta_{\text{R}} = 0.02,$ $S_0 = 0.3, \Delta T = 2, T_{\text{crit}} = 100,$ $Q_{\text{E}} = 2 \times 10^{-5}, R_{\text{pc}} = 1, \bar{m} = 0.5$ $\# 1, 2, 5, 7, 14, 16, 20, 23$ $\Delta t_{\text{cl}} = 10^{-4}, R_{\text{cl}} = 0.001, \eta_{\text{U}} = 0.2, \gamma_{\text{min}} = 10^{-6}$ $\alpha = 2.3, m_1 = 10.0, m_N = 0.2, \#20 = 1$ |



Data Structure

Singles $2N_p < i \leq N, \mathcal{N}_i = i$

KS $1 \leq i \leq 2N_p, i_p = i_{\text{icm}} - N$

C.m. $i > N, \mathcal{N} = N_0 + \mathcal{N}_k$

Triple KS + ghost, $\mathcal{N}_{\text{cm}} = -\mathcal{N}_k$

Ghost $\mathcal{N}_g = \mathcal{N}_{2i_p}, m_g = 0$

Quad KS + KS ghost, $\mathcal{N}_{\text{cm}} = -\mathcal{N}_k$

Quint T + KS, $\mathcal{N}_{\text{cm}} = -(2N_0 + \mathcal{N}_k)$

Chain $2N_p < i_{\text{cm}} \leq N, \mathcal{N}_{\text{cm}} = 0$

Escape $2N_p < i \leq N, r_i > 2r_{\text{tide}}$

Binary $i > N, r_i > 2r_{\text{tide}}, 2i_p - 1, 2i_p$

Hierarchy $i > N, r_i > 2r_{\text{tide}},$
.
 $2i_p - 1, 2i_p, i_{\text{ghost}}$

Units

(a) Scaling relations

Length scale R_V in pc and M_S in M_\odot

Fiducial velocity

$$\tilde{V}^* = 1 \times 10^{-5} (GM_\odot/L^*)^{1/2} \text{ km/s}$$
$$L^* = 3 \times 10^{18} \text{ cm}$$

Velocity unit $V^* = 6.5 \times 10^{-2} \left(\frac{NM_S}{R_V} \right)^{1/2} \text{ km/s}$

Fiducial time $\tilde{T}^* = (L^{*3}/GM_\odot)^{1/2} = 14.9 \text{ Myr}$

Time unit $T^* = \tilde{T}^* \left(\frac{R_V^3}{NM_S} \right)^{1/2} \text{ Myr}$

(b) Conversion from N-body units

$$\tilde{r} = R_V r \text{ pc}, \quad \tilde{v} = V^* v \text{ km/s}$$
$$\tilde{t} = T^* t \text{ Myr}, \quad \tilde{m} = M_S m M_\odot$$

Crossing time $T_{\text{cr}} = 2\sqrt{2} T^* \text{ Myr}$

Solar system $\tilde{v} = V^* \left(\frac{M}{a} \right)^{1/2}, \quad \tilde{t} = T^* \left(\frac{a^3}{M} \right)^{3/2}$

Scaling of Initial Conditions

| | |
|---------------------|---|
| Main input | $N, N_b, \bar{m}, R_{\text{pc}}$ |
| Cluster parameters | optional IMF and Plummer or King model |
| Initial data | $m_i, \tilde{\mathbf{r}}_i, \tilde{\mathbf{v}}_i, \dots, i = 1, N$ |
| Total energy | $E = T - U$ |
| Virial theorem | $\mathbf{v}_i = q \tilde{\mathbf{v}}_i, q = \left[\frac{Q_V U}{T} \right]^{1/2}, \mathbf{r}_i = \tilde{\mathbf{r}}_i$ |
| Standard units | $G = 1, \Sigma m_i = 1, E_0 = -0.25$ |
| Standard scaling | $\hat{\mathbf{r}}_i = \frac{\mathbf{r}_i}{S^{1/2}}, \hat{\mathbf{v}}_i = \mathbf{v}_i S^{1/2}, S = \frac{E_0}{q^2 T - U}$ |
| Astrophysical units | V^*, T^*, R^* from $M_{\text{tot}}, R_{\text{pc}}$ |
| Primordial binaries | split or copy m_i , introduce a, e, Ω |
| Force polynomials | $\mathbf{F}_i, \dot{\mathbf{F}}_i, \Delta t_i, \dots, i = 1, N$ |
| KS regularization | explicit initialization, $R < R_{\text{cl}}$ |

Energy Budget

Definition of total energy

$$E_{\text{tot}} = T + U + E_{\text{tide}} + E_{\text{bin}} + E_{\text{merge}} + E_{\text{coll}} + E_{\text{mdot}} + E_{\text{cdot}} + E_{\text{ch}} + E_{\text{sub}}$$

T Kinetic energy of single bodies and c.m. particles

U Potential energy of single and c.m. bodies

E_{tide} Tidal energy due to external perturbations

E_{bin} Binding energy in regularized pairs

E_{merge} Total internal energy of hierarchical systems

E_{coll} Sum of binding energies released in collisions

E_{mdot} Energy change from mass loss and Roche mass transfer

E_{cdot} Neutron star kicks and common envelope evolution

E_{ch} Total energy of any existing chain subsystem

E_{sub} Energy of unperturbed triple and quadruple subsystems

ΔE Energy change due to removal of escapers

Basic Variables

| | | |
|--------------------|-------|--|
| \mathbf{x}_0 | X0 | Primary coordinates |
| \mathbf{v}_0 | X0DOT | Primary velocity |
| \mathbf{x} | X | Prediction coordinates |
| \mathbf{v} | XDOT | Prediction velocity |
| \mathbf{F} | F | One half the total force (per unit mass) |
| $\mathbf{F}^{(1)}$ | FDOT | One sixth the total force derivative |
| m | BODY | Particle mass (also initial mass m_0) |
| Δt | STEP | Irregular time-step |
| t_0 | T0 | Time of last irregular force |
| \mathbf{F}_I | FI | Irregular force |
| \mathbf{D}_I^1 | FIDOT | First irregular force derivative |
| \mathbf{D}_I^2 | D2 | Second irregular force derivative |
| \mathbf{D}_I^3 | D3 | Third irregular force derivative |
| ΔT | STEPR | Regular time-step |
| T_0 | T0R | Time of last regular forcex |
| \mathbf{F}_R | FR | Regular force |
| \mathbf{D}_R^1 | FRDOT | First regular force derivative |
| \mathbf{D}_R^2 | D2R | Second regular force derivative |
| \mathbf{D}_R^3 | D3R | Third regular force derivative |
| R_s | RS | Neighbour sphere radius |
| L | LIST | Neighbour and perturber list |

KS Variables

| | | |
|----------------------|--------|---|
| \mathbf{U}_0 | U0 | Primary regularized coordinates |
| \mathbf{U} | U | Regularized prediction coordinates |
| \mathbf{U}' | UDOT | Regularized velocity |
| \mathbf{F}_U | FU | One half the regularized force |
| \mathbf{F}'_U | FUDOT | One sixth the regularized force derivative |
| $\mathbf{F}_U^{(2)}$ | FUDOT2 | Second regularized force derivative |
| $\mathbf{F}_U^{(3)}$ | FUDOT3 | Third regularized force derivative |
| h | H | Binding energy per unit reduced mass |
| h' | HDOT | First derivative of specific binding energy |
| $h^{(2)}$ | HDOT2 | Second derivative of binding energy |
| $h^{(3)}$ | HDOT3 | Third derivative of binding energy |
| $h^{(4)}$ | HDOT4 | Fourth derivative of binding energy |
| $\Delta\tau$ | DTAU | Regularized time-step |
| $t^{(2)}$ | TDOT2 | Second regularized derivative of time |
| $t^{(3)}$ | TDOT3 | Third regularized derivative of time |
| R | R | Two-body separation |
| R_0 | R0 | Initial value of the two-body separation |
| γ | GAMMA | Relative perturbation |

May 25, 12 12:29

Makefile

Page 1/1

```

SOURCE = \
nbody6.f adjust.f assess.f bindat.f binev.f binout.f binpop.f \
block.f bodies.f brake.f brake2.f brake3.f bsetid.f chaos0.f chaos.f \
check.f checkl.f chrect.f clint.f cloud.f cloud0.f cmbody.f \
cmcorr.f cmfirr.f cmfreg.f coal.f comenv.f core.f corerd.f \
cputim.f data.f decide.f define.f deform.f degen.f delay.f \
dgc core.f dtchck.f eccmod.f ecirc.f edot.f efac2.f efac3.f \
expel.f energy.f escape.f events.f evolve.f expand.f fclose.f \
fcloud.f fcorr.f fdisk.f fhalo.f ficorr.f findj.f findm.f \
flyby.f fnuc.f fpcorr.f fpert.f fpoly1.f fpoly2.f freeze.f \
gcinit.f gcint.f giant.f giant3.f gntage.f ggrad.f hcorr.f \
hiarch.f hicirc.f hidat.f higrow.f himax.f himax2.f himod.f \
hipop.f hirect.f histab.f hivel.f hmdot.f hmdot2.f hotsys.f \
hrdiag.f hrplot.f hut.f hut2.f iblock.f imf.f imfbd.f imf2.f \
impact.f induce.f inext.f input.f insert.f instar.f intgrt.f \
intide.f jacobi.f kepler.f kick.f kick2.f ksapo.f kscorr.f \
ksin2.f ksinit.f ksint.f kslist.f ksmod.f ksperi.f kspert.f \
kspoly.f kspred.f ksrect.f ksreg.f ksres.f ksres2.f ksterm.f \
kstide.f lagr.f lagr2.f levels.f magbrk.f matrix.f mdot.f merge.f \
merge2.f mix.f mloss.f mlwind.f modify.f mrenv.f mtrace.f mydump.f \
nbhist.f nbint.f nblist.f nbpot.f nbrem.f nbrest.f nbsort.f nbtide.f \
newtev.f nstab.f ntint.f offset.f orbit.f output.f peri.f permit.f \
pfac.f poti.f proto_star.f qtides.f ran2.f reflct.f regint.f \
remove.f rename.f reset.f reset2.f resolv.f rkint.f rl.f roche.f \
rpmax.f rpmax2.f rpmin.f scale.f search.f setup.f setup2.f shrink.f \
sort1.f spiral.f stability.f star.f start.f stepk.f steps.f stumpf.f \
subint.f swap.f sweep.f synch.f tail0.f tcirc.f tides.f tides2.f \
tides3.f touch.f tpert.f trdot.f trdot2.f trflow.f tstab.f tstep.f \
units.f unpert.f update.f verify.f xtrnl0.f xtrnld.f xtrnlf.f xtrnlp.f \
xtrnlt.f xtrnlv.f xvpred.f zare.f zcnsts.f zero.f zfuncs.f \
triple.f derqp3.f difsy3.f erel3.f extend.f qpmod3.f stabl3.f \
stablz.f start3.f subsys.f tperi.f trans3.f \
quad.f derqp4.f difsy4.f endreg.f erel4.f ichain.f newreg.f newsys.f \
qpmod4.f rchain.f rsort.f stabl4.f start4.f status.f trans4.f \
cfuncs.f chain.f chstab.f const.f cstab2.f cstab3.f cstab4.f cstab5.f \
derqp.f difsy1.f erel.f hpsort.f inclin.f invert.f ksphys.f physks.f \
qforce.f qpmod.f r2sort.f recoil.f redraw.f select.f slow.f stablc.f \
swcond.f switch.f transk.f transq.f transx.f vector.f xtf.f xtrnlu.f \
ycopy.f ysave.f \
absorb.f chaos2.f chdata.f chfind.f chfirr.f chinit.f chlist.f chmod.f \
chpert.f chpot.f chterm.f expel2.f fchain.f ghost.f giant2.f kcpert.f \
reduce.f reinit.f renew.f setsys.f tchain.f xcpred.f xtpert.f premsf.f \
circ.f spinup.f

```

Apr 05, 11 18:49

common6.h

Page 1/2

```

*      common6 .
*      -----
*
*      INCLUDE 'params.h'
*      IMPLICIT REAL*8   (A-H,O-Z)
*      REAL*8   MP,MP0,MPDOT
*
*      COMMON/NAMES/   NTOT,NPAIRS,NTTOT,N,NNBMAX,NCRIT,NFIX,NMERGE,NSUB,
&      IPHASE,IFIRST,ICOMP,JCOMP,ICLOSE,JCLOSE,JCMAX,
&      KSPAIR,NRUN,MODEL,NC,NZERO,NBZERO,NBIN0,NHI0,
&      NAME0,NCH,NCHAOS,IDUM1,KZ(50),NNBOPT,NEW2(8)
*
*      COMMON/PARAMS/  ETAI,ETAR,DTADJ,DELTAT,TCRIT,QE,RBAR,ZMBAR,
&      DTMIN,RMIN,ETAU,CMSEP2,ECLOSE,GMIN,GMAX,ETA0,
&      TWOPI,ONE3,ONE6,ONE9,ONE12,TCR0,TRH,BODYM,BODY1,
&      SMIN,RMIN2,RMIN22,STEPJ,ALPHA,ZNBMIN,ZNBMAX,EBH,
&      TIME,TADJ,TNEXT,CPU,CPU0,CPUTOT,ZMASS,RSCALE,TCR,
&      TRC,BE(3),CMR(4),CMRDOT(4),ZKIN,POT,EBIN,EBIN0,
&      ESUB,EMERGE,ECOLL,EDISS,ESYNC,E(12),ERROR,ERRTOT,
&      DETOT,ETCORR,AZ,PCRIT,EBCH0,RTIDE,TSCALE,TIDAL(4),
&      HT,ETIDE,EGRAV,RSFAC,RSPH2,RC,RC2,RC2IN,VC,ZMC,
&      RDENS(3),RHOD,RHOM,RSMIN,RMAX,DMIN1,DMIN2,DMIN3,
&      DMIN4,DMINC,SBCOLL,BBCOLL,CHCOLL,DELTAS,ORBITS(9),
&      GPRINT(9),TLASTT,TLASTS,TLASTB(9),TDUMP,
&      SCOEFF(12),TOFF,TTOT,EBESC,EMESC,ESESC,CLIGHT,
&      RZ,TINY,SMAX,WTOT,WTOT0,VRMS,DUMMY(97)
*
*      COMMON/COUNTS/  NSTEPI,NSTEPB,NSTEPQ,NNPRED,NBCORR,NBFULL,NBVOID,
&      NNTB,NBSMIN,NLSMIN,NBDIS,NBDIS2,NCMDER,NBDER,
&      NFAST,NBFAST,NBLOCK,NBPRED,NICONV,NCHAIN,NSTEPB,
&      NKSTRY,NKSREG,NKSHYP,NKSPER,NPRECT,NEWKS,NKSMOD,
&      NTTRY,NTRIP,NQUAD,NMERG,NSTEPB,NSTEPQ,NDISS,NTIDE,
&      NCOLL,NSYNC,NSESC,NBESC,NMESC,NTIMER,NSTEPS,NPRINT,
&      NDUMP,NBPREV,NEWHI,NSTEPB,NBFLUX,NMTRY,NWARN,
&      NIRECT,NURECT,NBRECT,NRRECT,KSMAG,NOFL(2),NPOP(10),
&      NBLCKR,NDUMMY(99)
*
*      COMMON/PLPOT/   MP,AP2,VIR,MP0,MPDOT,TDELAY,RTIDE0,QVIR,PLDUM(4)
*
*      COMMON/BLOCKS/  TPREV,TBLOCK,DTK(40),KVEC(2*KMAX)
*
*      COMMON/STARS/   EPOCH0,ZMRG,ZMHE,ZMRS,ZMWD,ZMSN,ZMNH,ZMBH,ZMDOT,
&      AU,PC,GM,DAYS,YRS,SU,SMU,RAU,TSTAR,VSTAR,STEPX,
&      TMDOT,TPHYS,TURN,EMDOT,ECDOT,EKICK,TPLOT,DTPLOT,
&      XHYD,YHEL,ZMET,ZPARS(20),SPNFAC,IQCOLL,NAS,NBH,
&      NBKICK,NBR,NBRK,NBS,NCHA,NCIRC,NCOAL,NCONT,NDD,
&      NEMOD,NGB,NGLOB,NGLOB0,NHE,NHG,NHI,NHYP,NKICK,
&      NMDOT,NMS,NNH,NRG,NRO,NROCHE,NRS,NRSAVE,NSHOCK,
&      NSLP,NSN,NSP,NSPIR,INSTAB,NTZ,NWD,NCE,NHYPC,NBH0,
&      ITYPE(5),KSAVE(4),KTYPE(0:14,0:14),NEINT,IBLUE,
&      ITAIL0,NTAIL,NTDUM,NSTAIL,N1,NGDUM(7),
&      LISTR(MLR),LISTD(MLD),LISTV(MLV)

```

Apr 05, 11 18:49

common6.h

Page 2/2

```

COMMON/NBODY/  X(3,NMAX),X0(3,NMAX),X0DOT(3,NMAX),F(3,NMAX),
&              FDOT(3,NMAX),BODY(NMAX),RS(NMAX),XDOT(3,NMAX),
&              FI(3,NMAX),D1(3,NMAX),D2(3,NMAX),D3(3,NMAX),
&              FR(3,NMAX),D1R(3,NMAX),D2R(3,NMAX),D3R(3,NMAX),
&              STEP(NMAX),T0(NMAX),STEPR(NMAX),TOR(NMAX),
&              TNEW(NMAX),RADIUS(NMAX),TEV(NMAX),TEV0(NMAX),
&              BODY0(NMAX),EPOCH(NMAX),SPIN(NMAX),XSTAR(NMAX),
&              ZLMSTY(NMAX),FIDOT(3,NMAX),D0(3,NMAX),
&              FRDOT(3,NMAX),D0R(3,NMAX),KSTAR(NMAX)

```

*

```

COMMON/PAIRS/  U(4,KMAX),U0(4,KMAX),UDOT(4,KMAX),FU(4,KMAX),
&              FUDOT(4,KMAX),FUDOT2(4,KMAX),FUDOT3(4,KMAX),
&              H(KMAX),HDOT(KMAX),HDOT2(KMAX),HDOT3(KMAX),
&              HDOT4(KMAX),DTAU(KMAX),TDOT2(KMAX),TDOT3(KMAX),
&              R(KMAX),R0(KMAX),GAMMA(KMAX),SF(7,KMAX),H0(KMAX),
&              FP0(4,KMAX),FD0(4,KMAX),TBLIST,DTB,KBLIST(KMAX),
&              KSLOW(KMAX),NAME(NMAX),LIST(LMAX,NMAX)

```

*

```

COMMON/LISTS/  ILLIST(NMAX),JLIST(NMAX),JPERT(5*LMAX)

```

GPU/SSE with NBODY6

| Version | Regular force | Irregular force |
|--------------|---------------|-----------------|
| Standard | 1 CPU | 1 CPU |
| OpenMP | 4 CPU | 4 CPU |
| OpenMP + SSE | 4 CPU + SIMD | 4 CPU * |
| GPU | 1 CPU + GPU | 1 CPU * |
| GPU2 | 1 CPU + 2GPU | 1 CPU * |

*: irregular force in parallel C++ & Real*4/8

GPU: neighbour lists and fast potential

Getting Started

1. Download code `nbody6.tar.gz`
2. Unzip `gunzip nbody6.tar.gz`
3. Extract files `tar xvf nbody6.tar`
4. Check `params.h` `NMAX, LMAX, KMAX, MMAX`
5. Compile the code `make nbody6`
6. Create run directory `mkdir Run`
7. Run test input `time nbody6 <input >output &`
8. Profiling `Makefile with -O3 -pg`
9. Performance data `gprof nbody6 gmon.out -p >OUT`

