Direct N-Body Codes

NBODY1	ITS	ϵ	$3 - 100$
NBODY1H	ITS	ϵ	$10 - 10^5$
NBODY2	ACS	ϵ	$50 - 10^4$
NBODY2H	HACS	ϵ	$50 - 10^4$
NBODY3	ACS	KS & MREG	$3 - 100$
NBODY4	HITS	KS & MREG	$10 - 10^5$
NBODY5	ACS	KS & MREG	$50 - 10^4$
NBODY6	HACS	KS & MREG	$50 - 10^4$
NBODY7	HITS	KS & 2 BH	$10 - 10^5$
SPOKE	HITS	KS & 1 BH	$10 - 10^5$
HERMIT4	HITS	KS & SUN	$10 - 10^4$

MREG: Three-body, four-body & chain regularization

http://www.ast.cam.ac.uk/~sverre

Units

(a) Scaling relations

Given length scale $R_{\rm V}$ in pc and total mass $NM_{\rm S}$ in $M_\odot$

Velocity scaling

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

Velocity unit $\quad V^* = 6.557\times 10^{-2}(NM_{\rm S}/R_{\rm V})^{1/2}\,{\rm km/s}$

Fiducial time $\quad \tilde{T}^* = (L^{*3}/GM_\odot)^{1/2} = 14.94$ Myr

Time unit $\quad T^* = 14.94\,(R_{\rm V}^3/NM_{\rm S})^{1/2}$ Myr

(b) Conversion from N-body to physical units

$\tilde{r} = R_{\rm V}\, r$ pc, $\quad \tilde{v} = V^*\, v\ km/s, \quad \tilde{t} = T^*\, t$ Myr, $\quad \tilde{m} = M_{\rm S}\, m\ M_\odot$

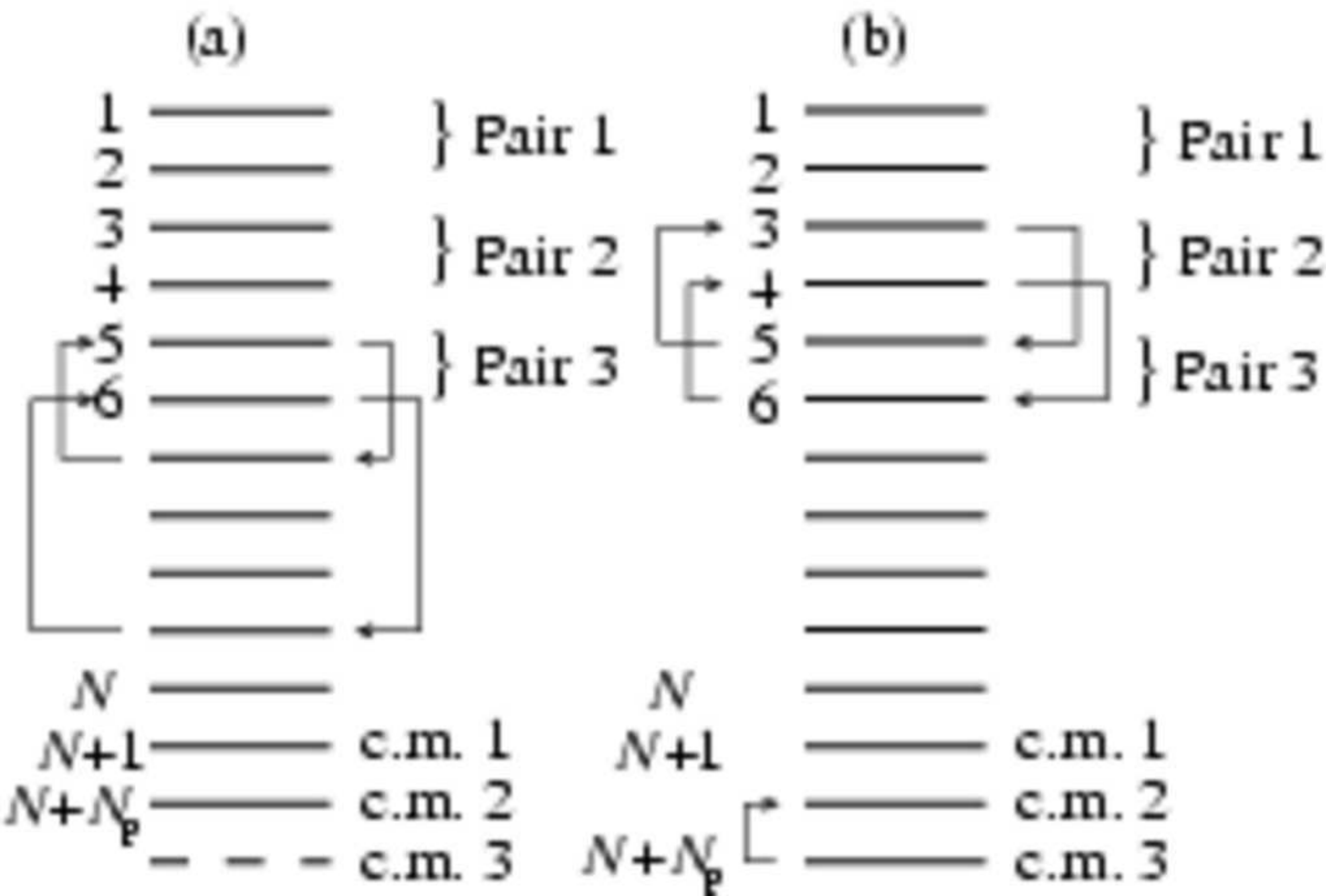
Crossing time $\quad T_{\rm cr} = 2\sqrt{2}\,T^*$ Myr

Scaling of Initial Conditions

Main input	$N, \;\; N_{\rm b}, \;\; \bar{m}, \;\; R_{\rm pc}$
Cluster parameters	optional IMF and Plummer or King model
Initial data	$m_i, \, \tilde{\mathbf{r}}_i, \, \tilde{\mathbf{v}}_i, ..., \, i = 1, \, N$
Total energy	$E \, = \, T \, - \, U$
Virial theorem	$\mathbf{v}_i = q \, \tilde{\mathbf{v}}_i, \;\; q \, = \, \left[\frac{Q_{\rm V} U}{T} \right]^{1/2}, \;\; \mathbf{r}_i \, = \, \tilde{\mathbf{r}}_i$
Standard units	$G = 1, \;\; \sum m_i \, = \, 1, \;\; E_0 \, = \, -0.25$
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 $M_{\rm tot}, \, R_{\rm pc}$
Primordial binaries	split or copy m_i, introduce $a, \, e, \, \Omega$
Force polynomials	$\mathbf{F}_i, \, \dot{\mathbf{F}}_i, \, \Delta t_i, ..., \; i = 1, \, N$
KS regularization	explicit initialization, $R \, < \, R_{\rm cl}$

Data Structure

Single stars	$2\,N_{\rm p} < i \leq N, \quad \mathcal{N}_i = i$
KS pairs	$1 \leq i \leq 2\,N_{\rm p}\,, \quad i_p = i_{\rm icm} - N$
C.m. particles	$i > N, \quad \mathcal{N} = N_0 + \mathcal{N}_k\,, \quad k = 2i_p - 1$
Stable triples	KS + ghost, $\mathcal{N}_{\rm cm} = -\mathcal{N}_k$
Ghost particles	$\mathcal{N}_{\rm ghost} = \mathcal{N}_{2i_{\rm p}-1}\,, \quad m_{\rm ghost} = 0$
Stable quadruples	KS + KS ghost, $\mathcal{N}_{\rm cm} = -\mathcal{N}_k$
Higher orders	T + KS, $\mathcal{N}_{\rm cm} = -(2N_0 + \mathcal{N}_k)$
Chain members	$2\,N_{\rm p} < i_{\rm cm} \leq N, \quad \mathcal{N}_{\rm cm} = 0$
Single escape	$2N_{\rm p} < i \leq N, \quad r_i > 2r_{\rm tide}\,,$ remove i
Binary escape	$i > N\,, \quad r_i > 2r_{\rm tide}\,, \quad 2i_p - 1,\ 2i_p$
Hierarchy escape	$i > N\,, \quad r_i > 2r_{\rm tide}\,, \quad 2i_p - 1,\ 2i_p\,,\ i_{\rm ghost}$


(a)
(b)
1
2
3
4
5
6
N
N+1
N+N_p
Pair 1
Pair 2
Pair 3
c.m. 1
c.m. 2
c.m. 3

A Dynamical Zoo

(a) Concepts

Single stars	S
Binaries	B
Long-lived triples	T = [B,S]
Quadruples	Q = [B,B]
Higher-order systems	H = [T,T]
Ghosts	G

(b) Treatments

S: Basic integration

B: Relative two-body motion and c.m. integration

T: Outer orbit around inner c.m. and c.m. integration

Q: Two binaries in relative orbit, etc.

G: Skip integration