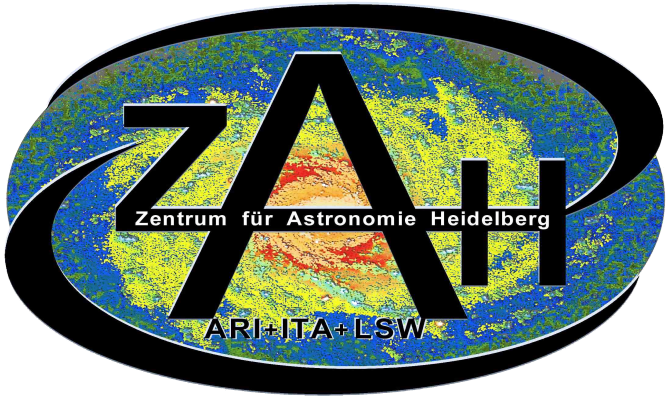


The volume of star clusters

Andreas Ernst, ARI Heidelberg

Modest-13 Workshop
Almaty, Kasachstan

organized by Chingis Omarov
and his TEAM

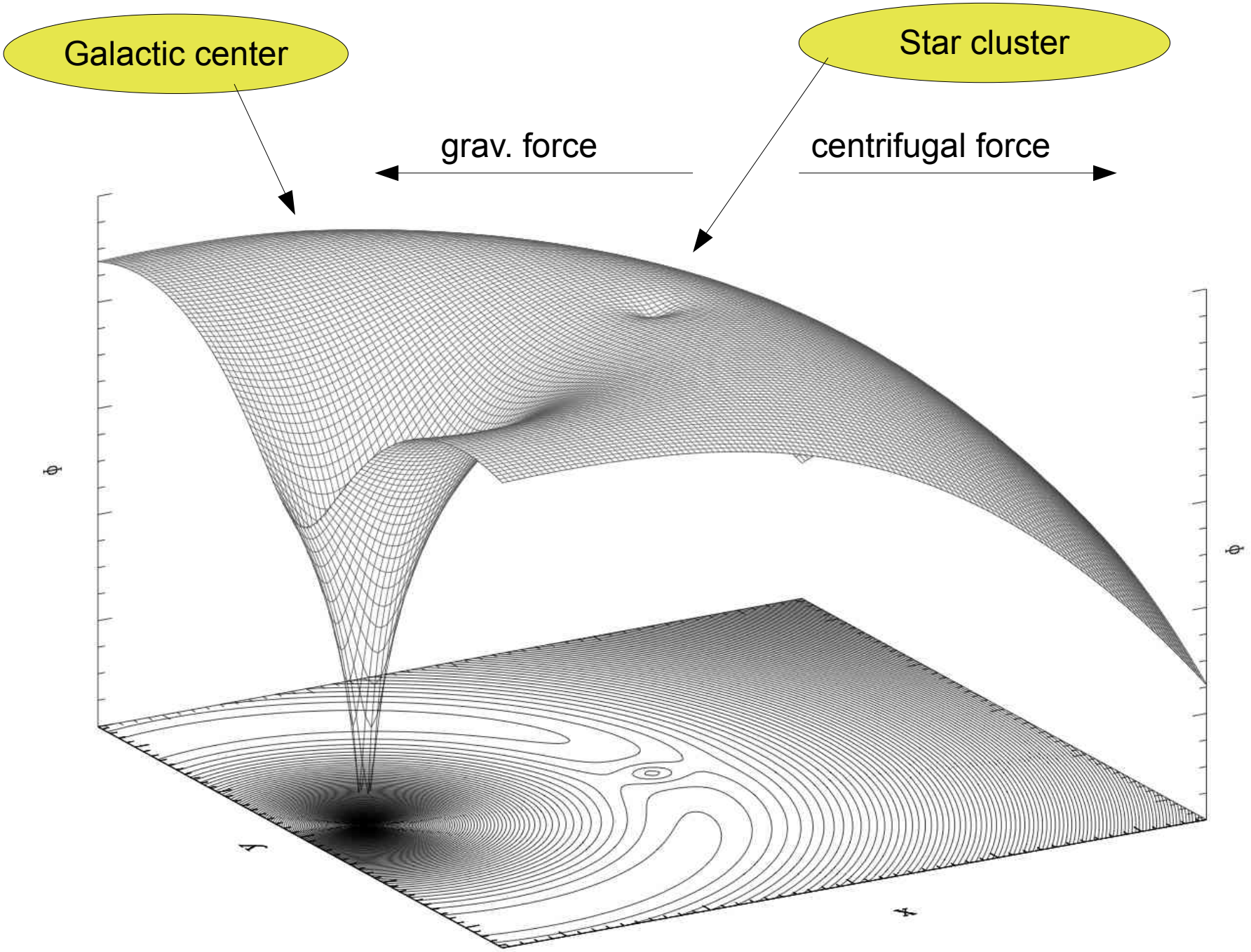
At Assy-Turgen Mountain Observatory

Observing Trip
with **Site Testing**,
August 15-16, 2013
organized by **Maxim Krugov**

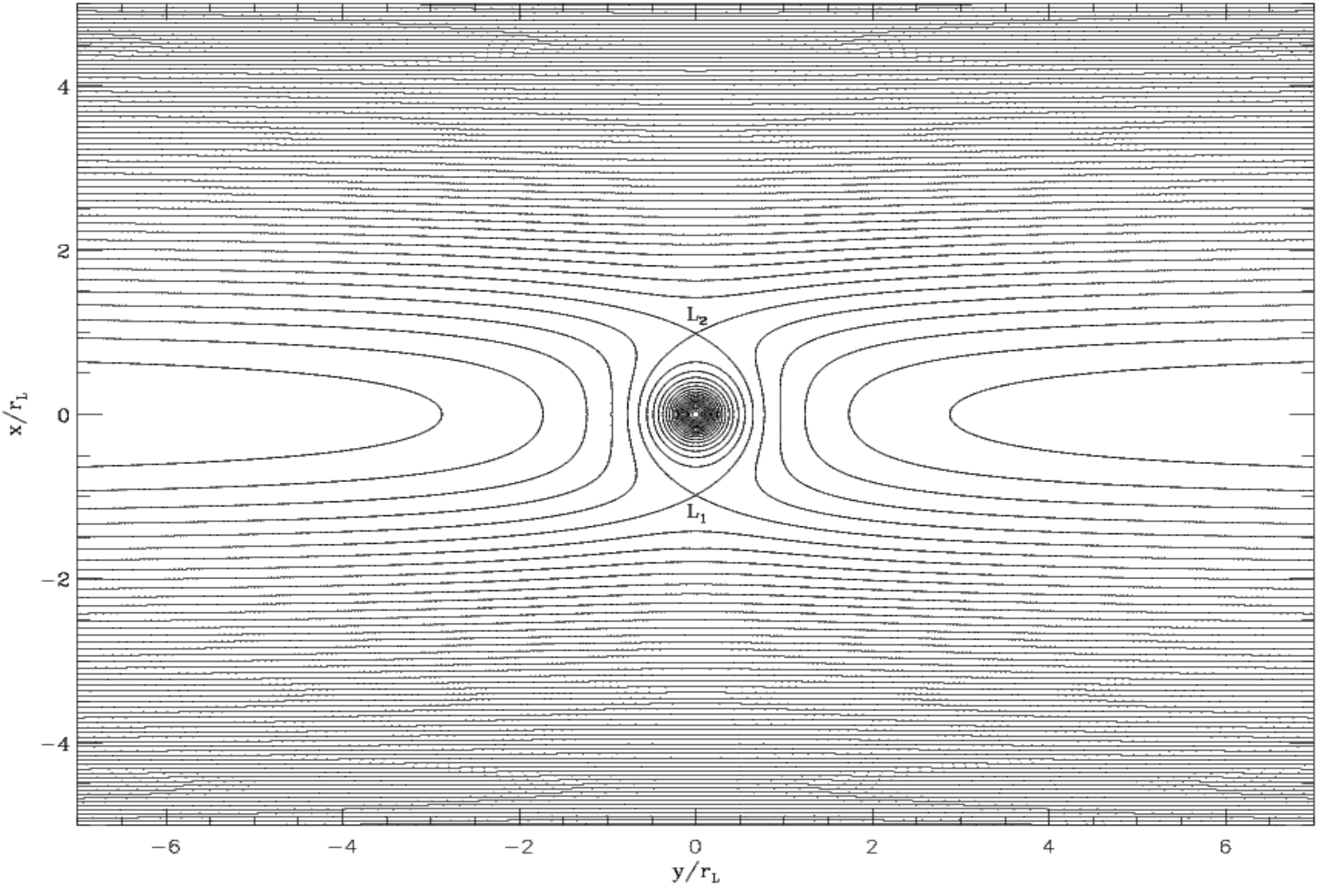
Outline

- Roche volume – what is it?
- Roche volume filling
- Difference GCs/OCs
- Evolution in the Roche volume
  - underfilling regime
  - overfilling regime

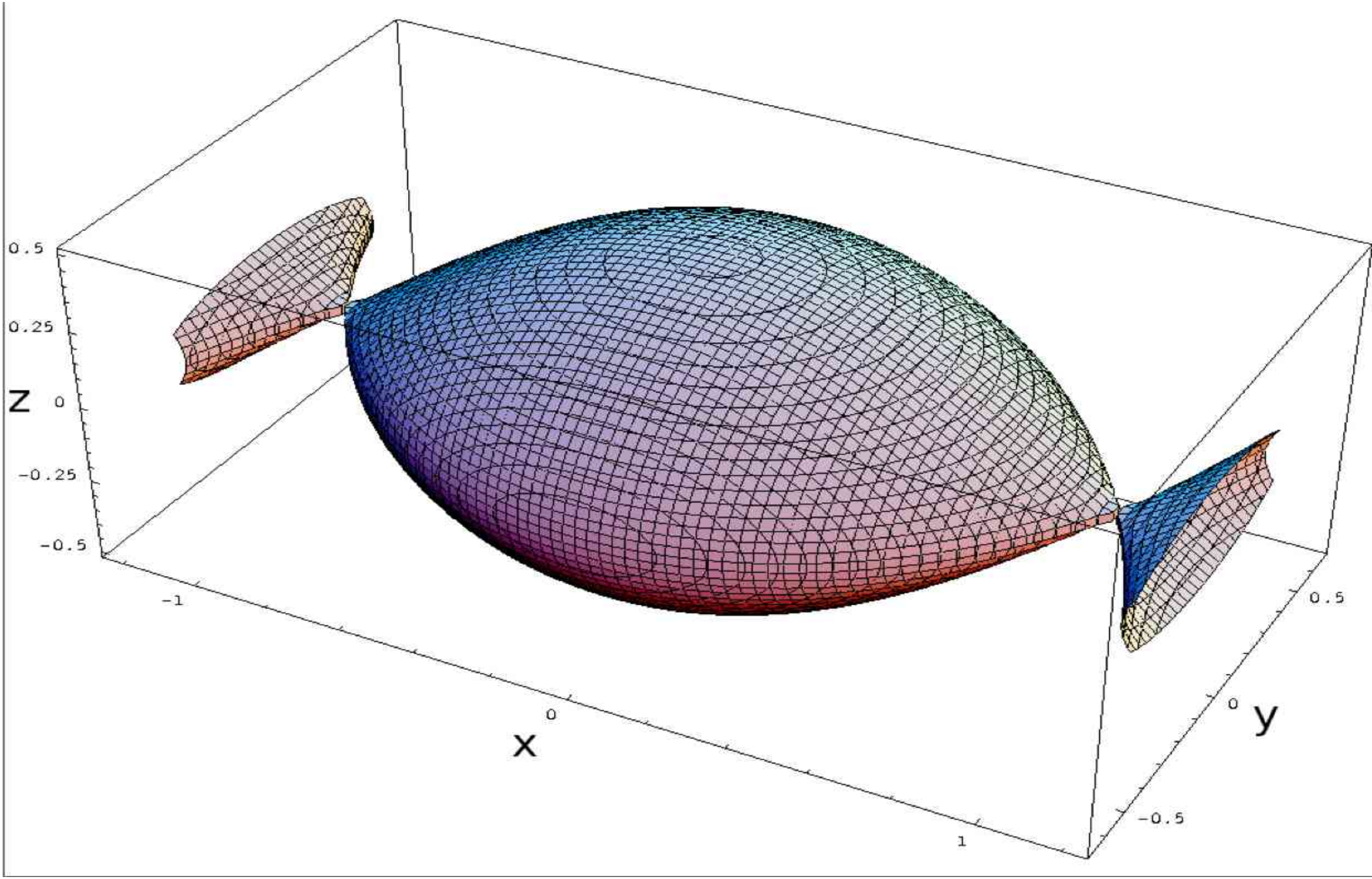
Star cluster in a tidal field



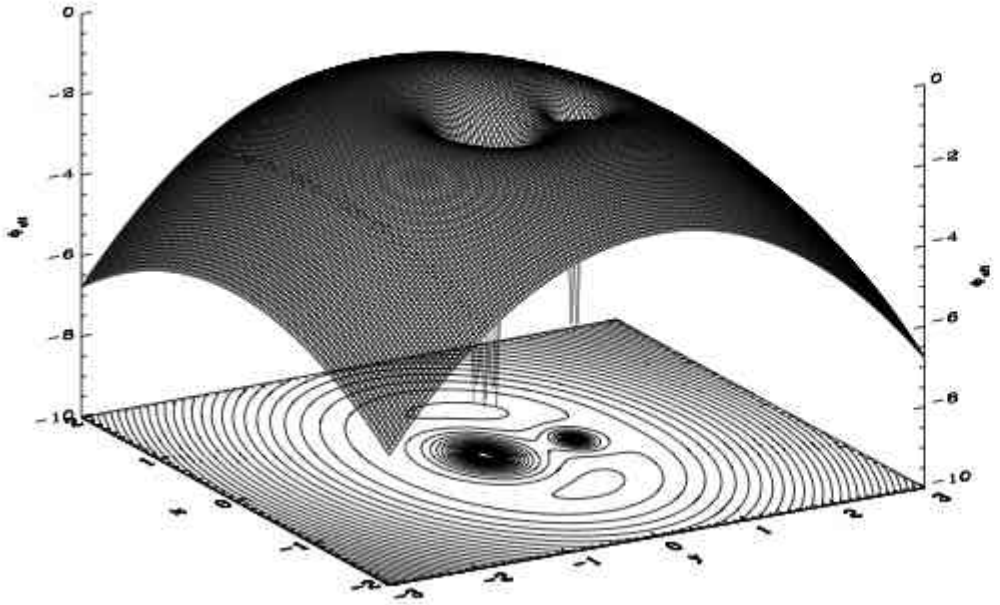
Jacobi radius



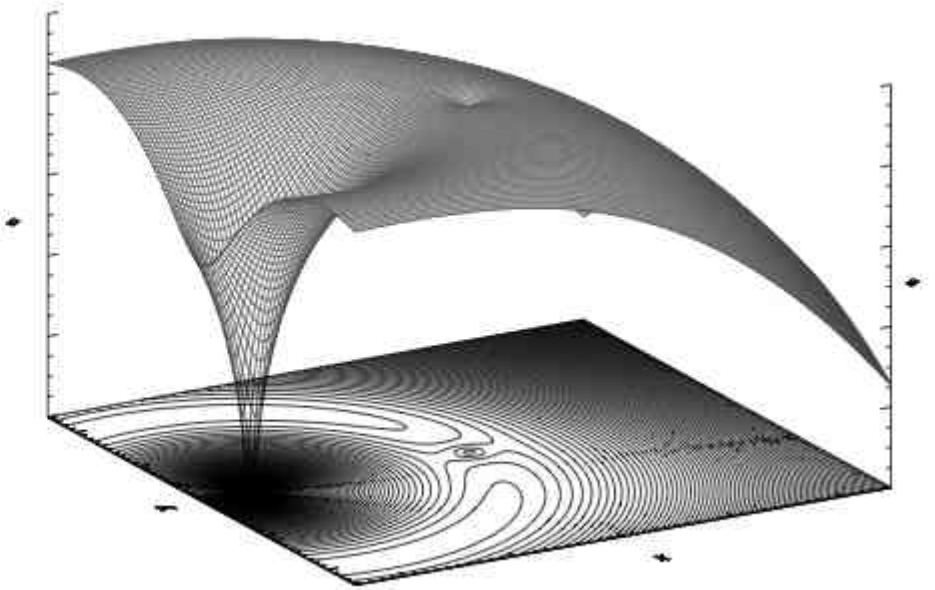
The Roche volume



„Roche lobe“ and „Roche volume“



Roche lobe

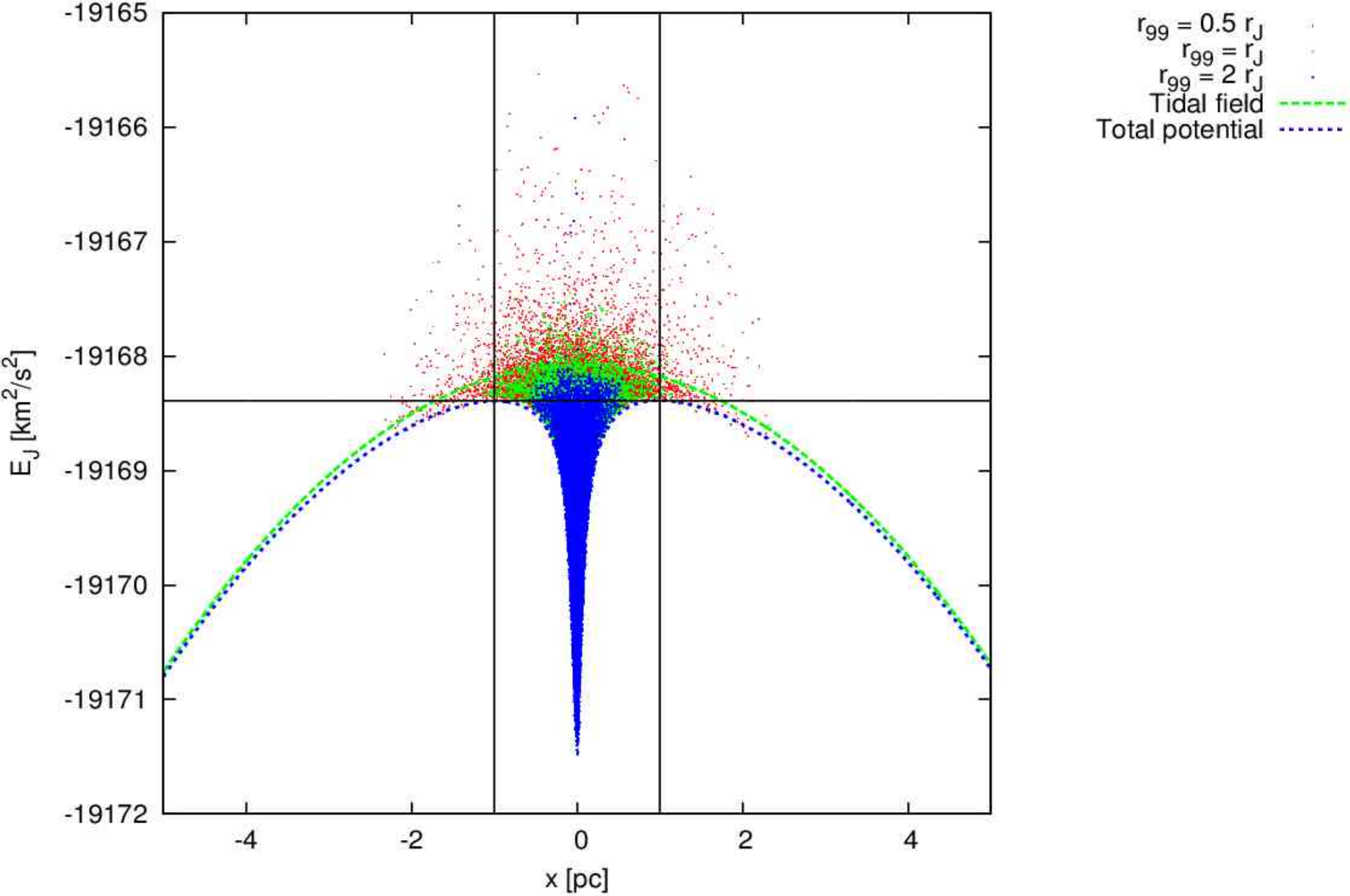


Roche volume

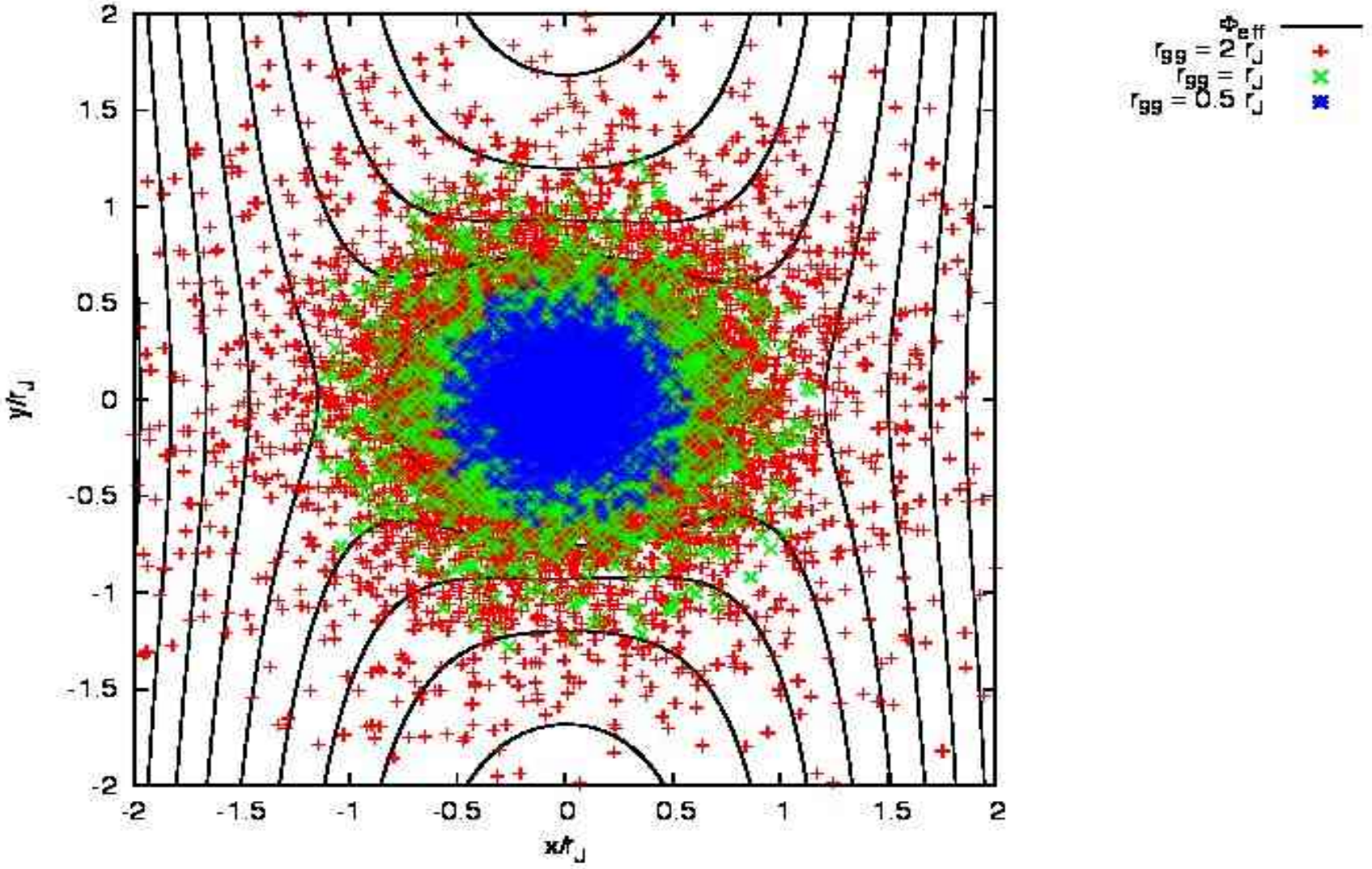
Questions / Thoughts

- To what extent do open and globular clusters fill the Roche volume?
- What is the difference between open and globular clusters with respect to Roche volume filling?
- Jacobi radius provides a natural scale
- Another scale is given by the position/width of the main resonant island

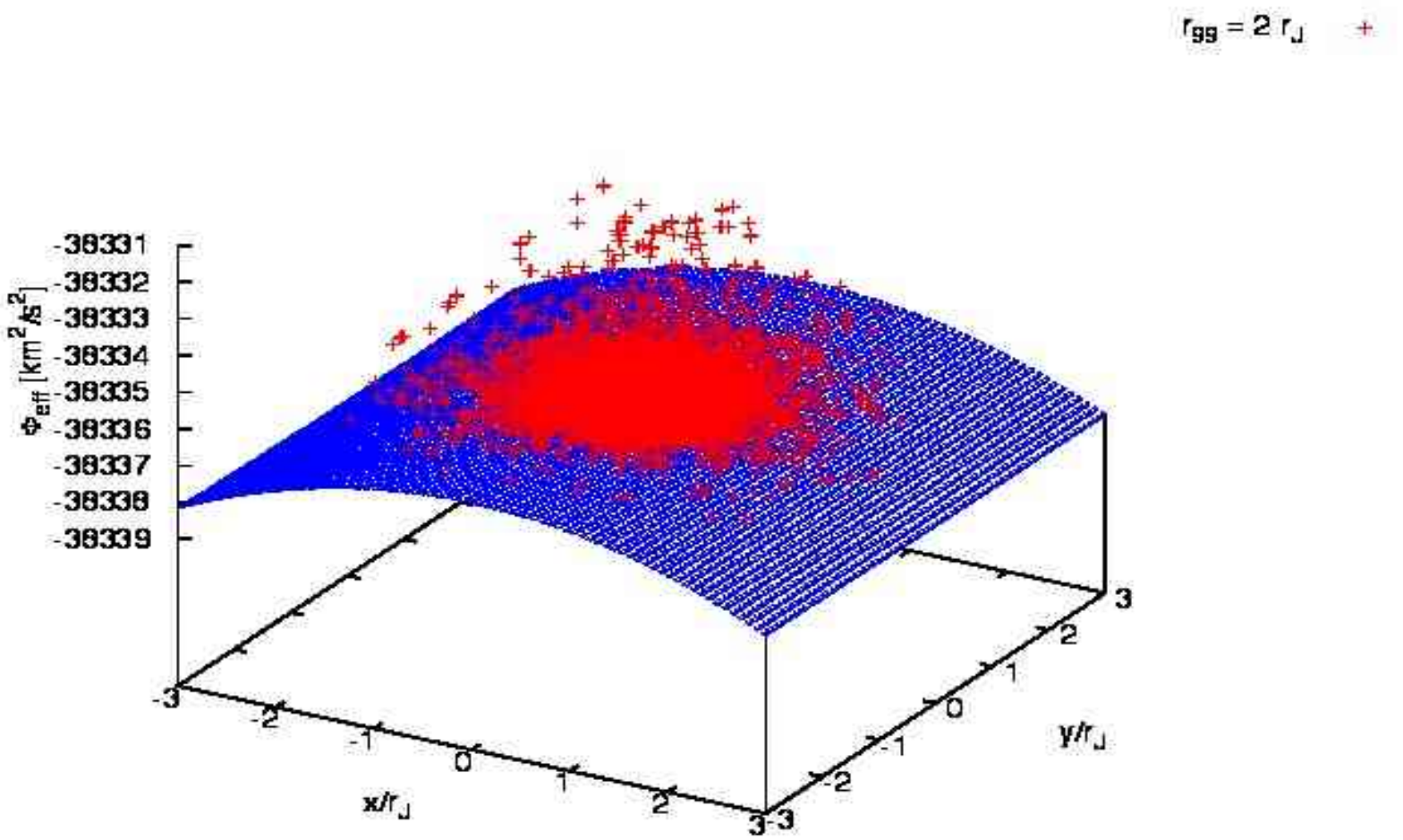
Roche-volume filling 1



Roche volume filling 2



Roche volume filling 3



The ratio r_h/r_J

$$r_J = \left[\frac{GM_{cl}}{(4-\beta^2)\Omega^2}\right]^{1/3}, \qquad \beta = \frac{\kappa}{\Omega}, \qquad M_{cl} = \frac{8\pi}{3}\rho\, r_h^3$$

for OCs:
$$\frac{r_h}{r_J} = \left[\frac{3(4-\beta^2)\Omega^2}{4\pi G\rho}\right]^{1/3} = \left(\frac{4-\beta^2}{2}\right)^{1/3}\left(\frac{t_{orb}}{T_{orb}}\right)^{2/3}$$

for GCs:
$$\frac{r_h}{r_J(t)} = \left(\frac{t_{orb}}{2\pi}\right)^{2/3}\left(\frac{V_C^2}{2}\right)^{1/3}\left(\frac{R_g^2+R(t)^2}{R(t)^4}\right)^{2/3}$$

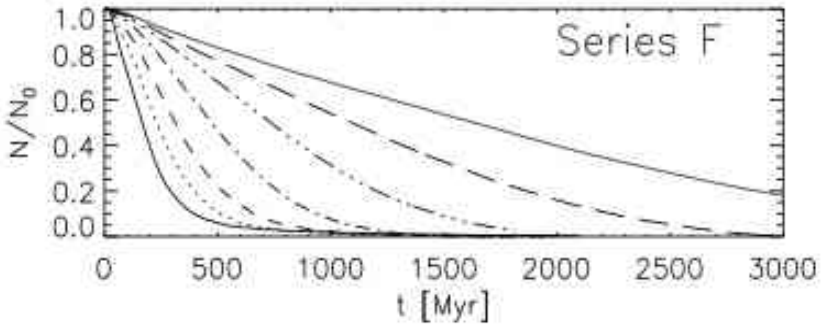
Ernst & Just (2013)

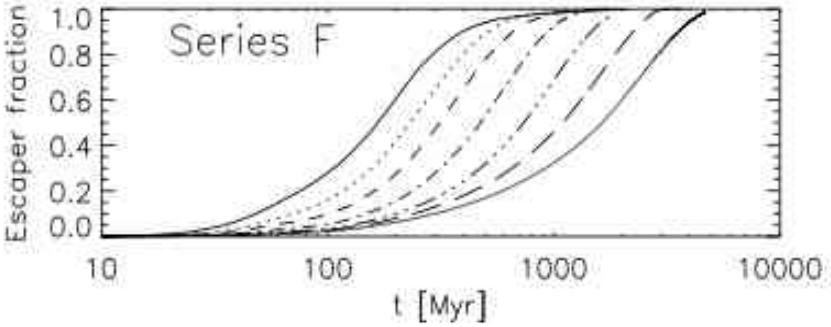
Parameter space

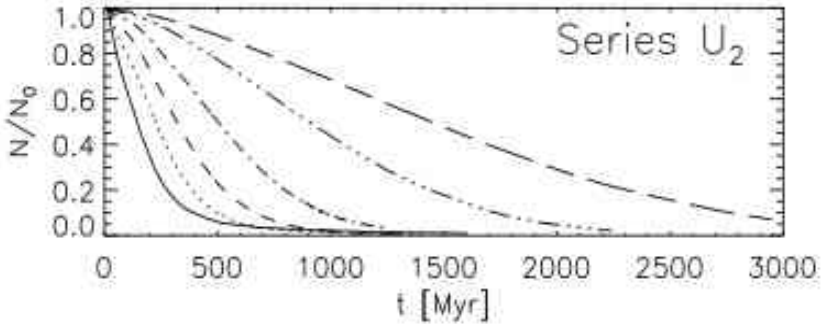
Series	F	U_1	U_2	O_1	O_2	O_3
W_0	6	6	6	6	6	6
$\lambda = r_h/r_J$	0.149	0.111	0.074	0.222	0.446	0.669
$\lambda' = r_{99\%}/r_J$	2/3	1/2	1/3	1	2	3
$\widehat{\lambda} = r_{100\%}/r_J$	1	3/4	1/2	3/2	3	9/2
R_g [kpc]	8	8	8	8	8	8
(N, n)	F	U_1	U_2	O_1	O_2	O_3
$(200, 128)$	+	+	+	+	+	+
$(500, 64)$	+	+	+	+	+	+
$(1\text{k}, 32)$	+	+	+	+	+	+
$(2\text{k}, 16)$	+	+	+	+	+	+
$(5\text{k}, 8)$	+	+	+	+	+	+
$(10\text{k}, 4)$	+	+	+	+	+	+
$(20\text{k}, 2)$	+	-	-	+	+	+
$(50\text{k}, 1)$	-	-	-	+	-	-

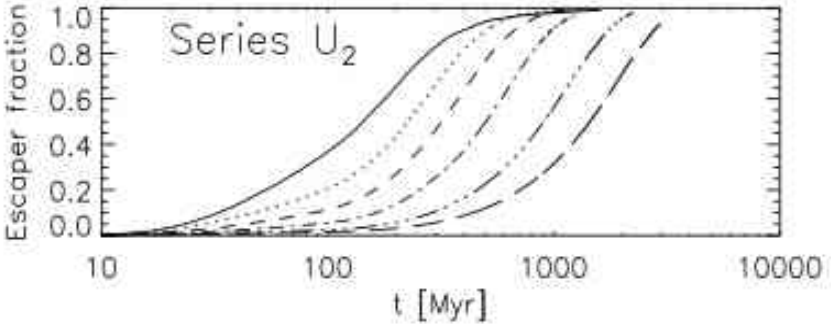
Ernst, Berczik, Just, subm.

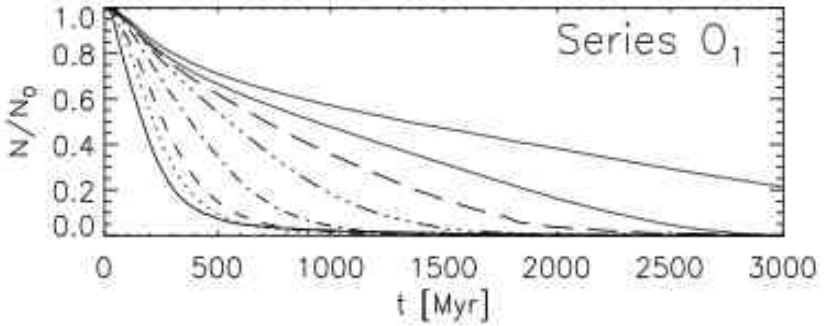
Evolution 1

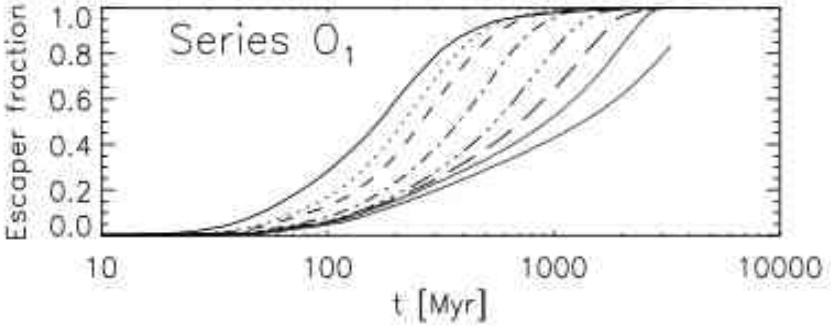






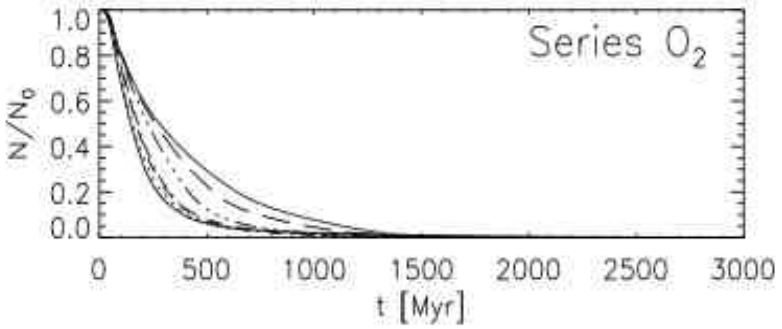


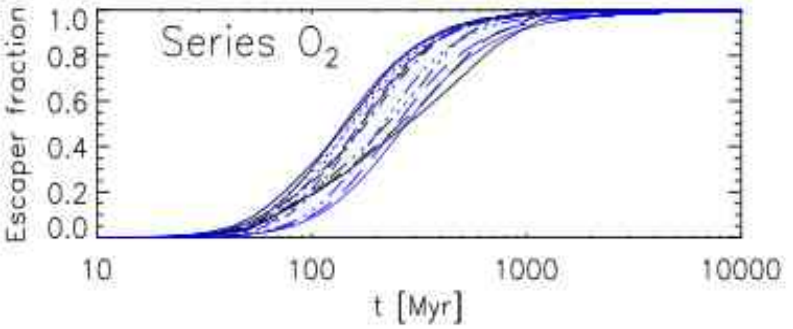


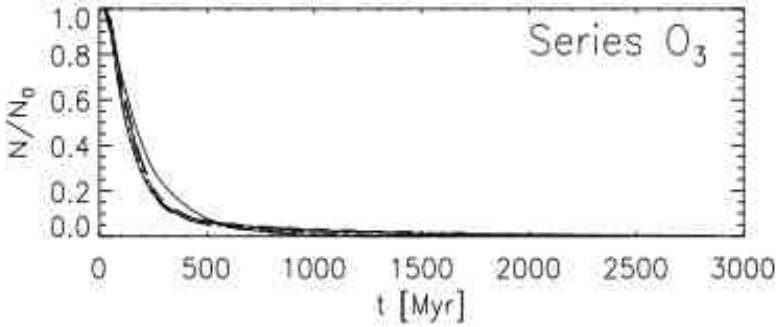


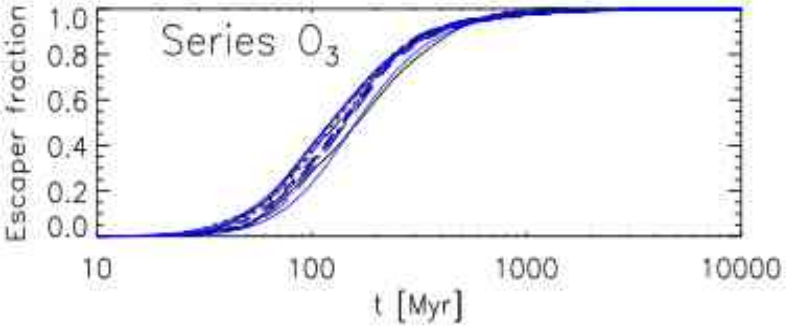
Ernst, Berczik, Just, subm.

Evolution 2









Ernst, Berczik, Just, subm.

Pseudo-logistic growth

$$\frac{d \ln N_e}{d \ln t} = \kappa \left(1 - \frac{N_e}{N_0} \right)$$

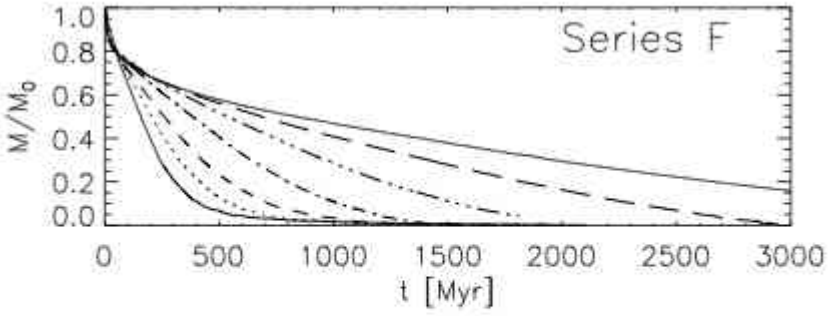
Solution:

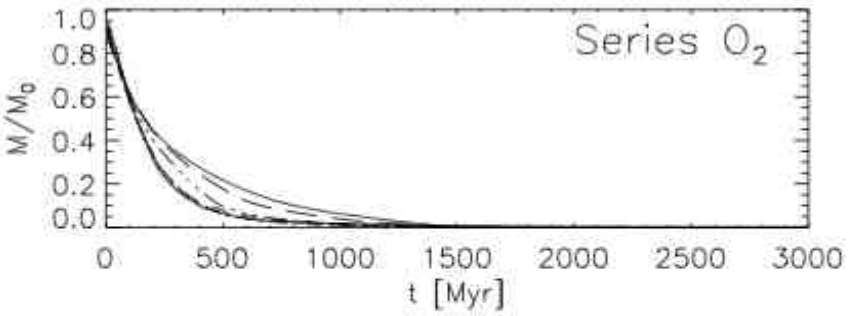
$$\frac{N_e}{N_0} = \frac{t^{\kappa}}{t_{50}^{\kappa} + t^{\kappa}}$$

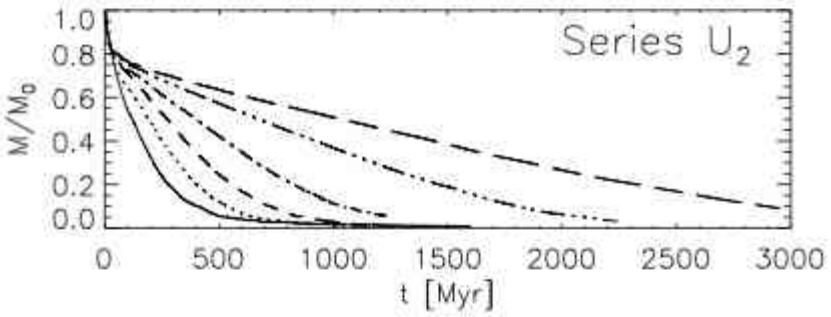
$$\frac{N}{N_0} = \frac{t_{50}^{\kappa}}{t_{50}^{\kappa} + t^{\kappa}}$$

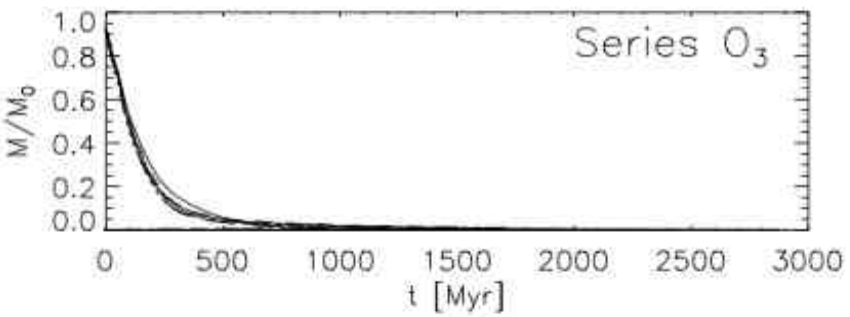
Ernst, Berczik, Just, subm.

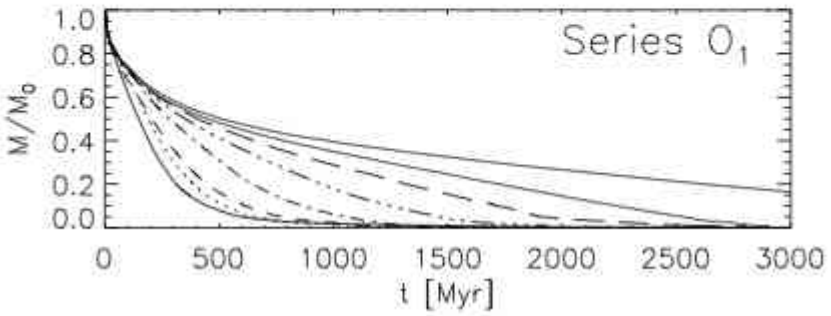
Evolution 3





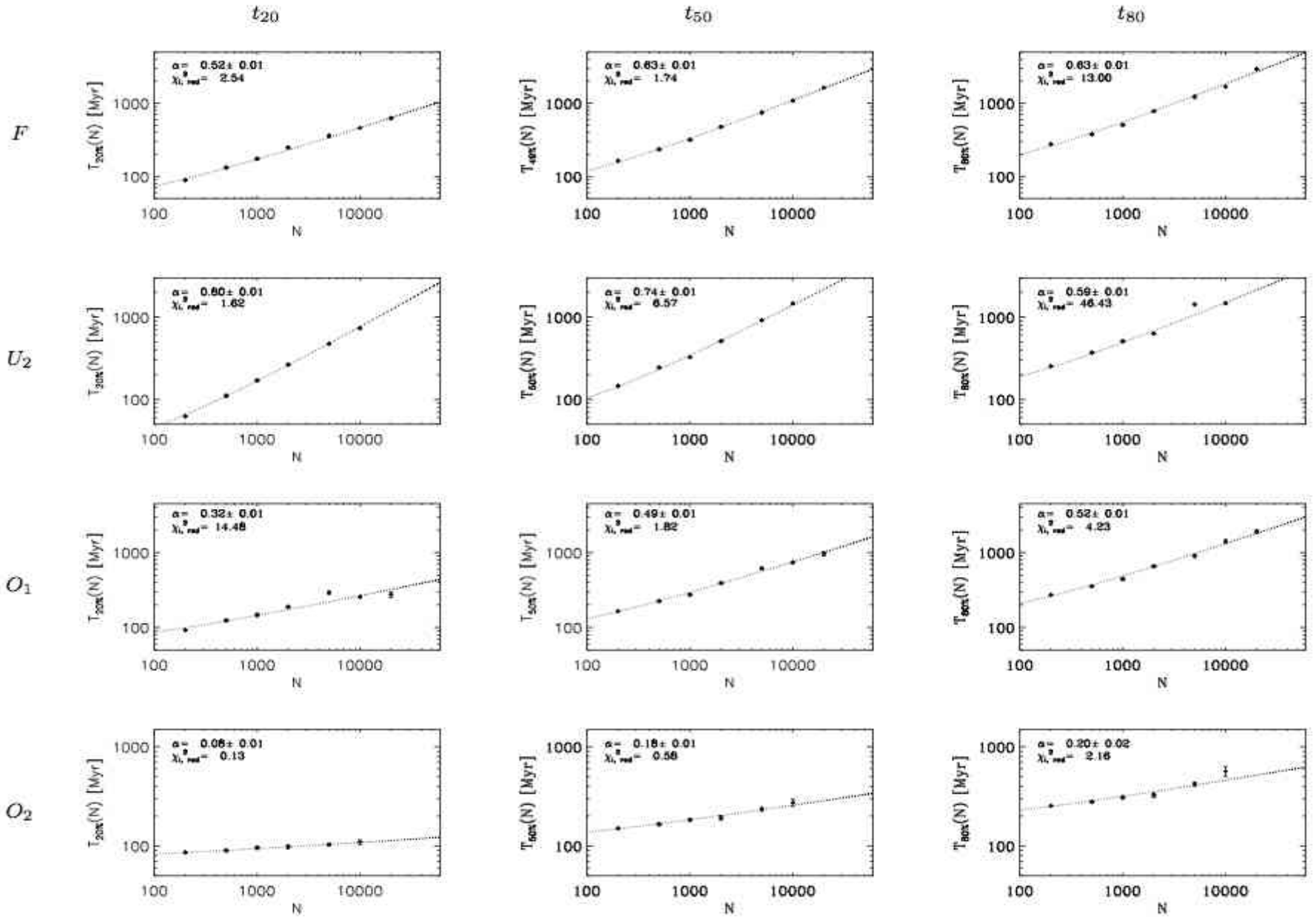






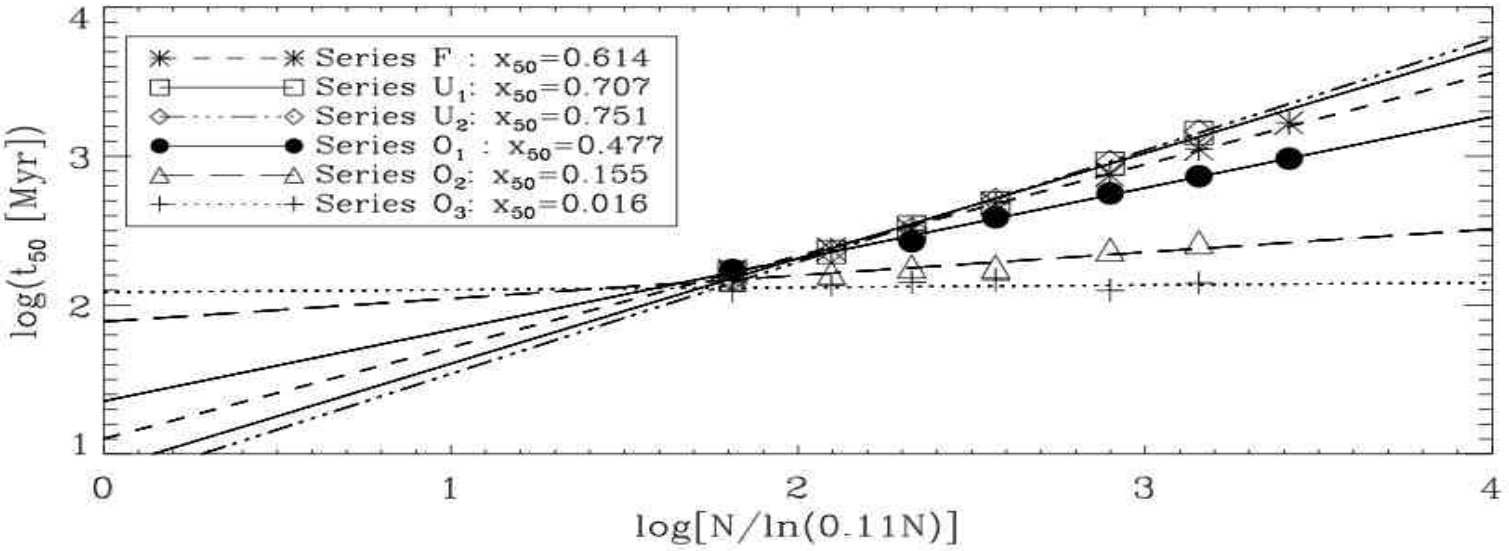
Ernst, Berczik, Just, subm.

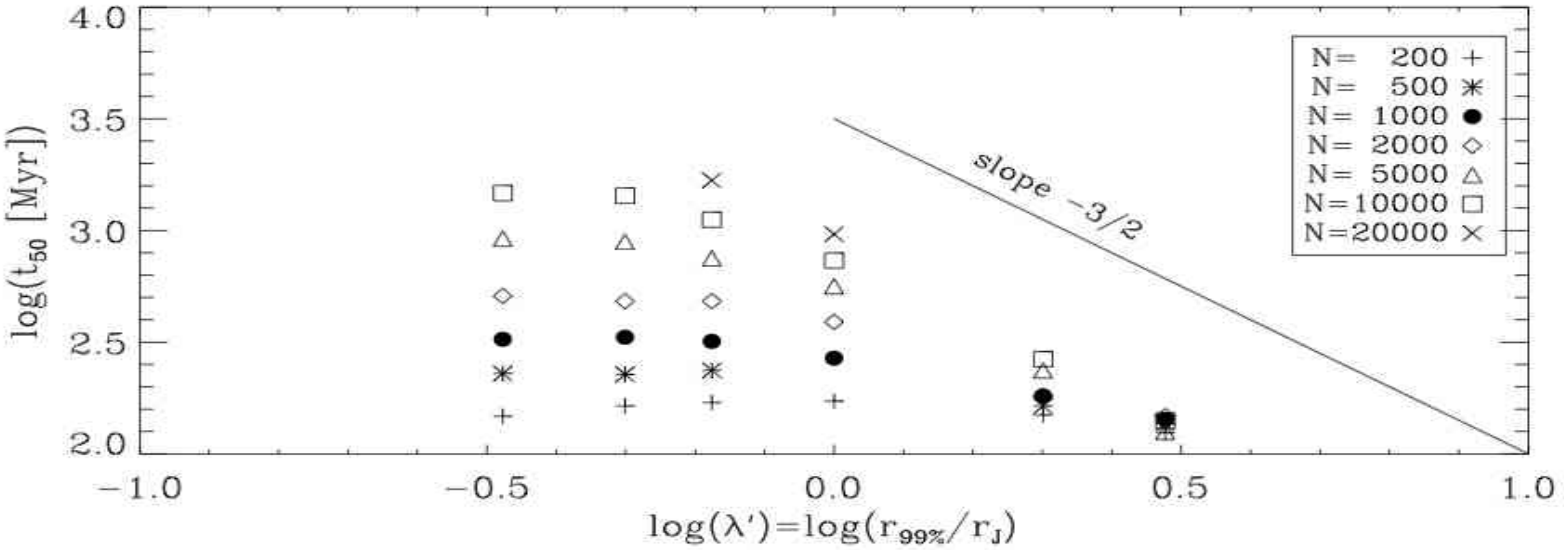
Fitting 1



Ernst, Berczik, Just, subm.

Fitting 2

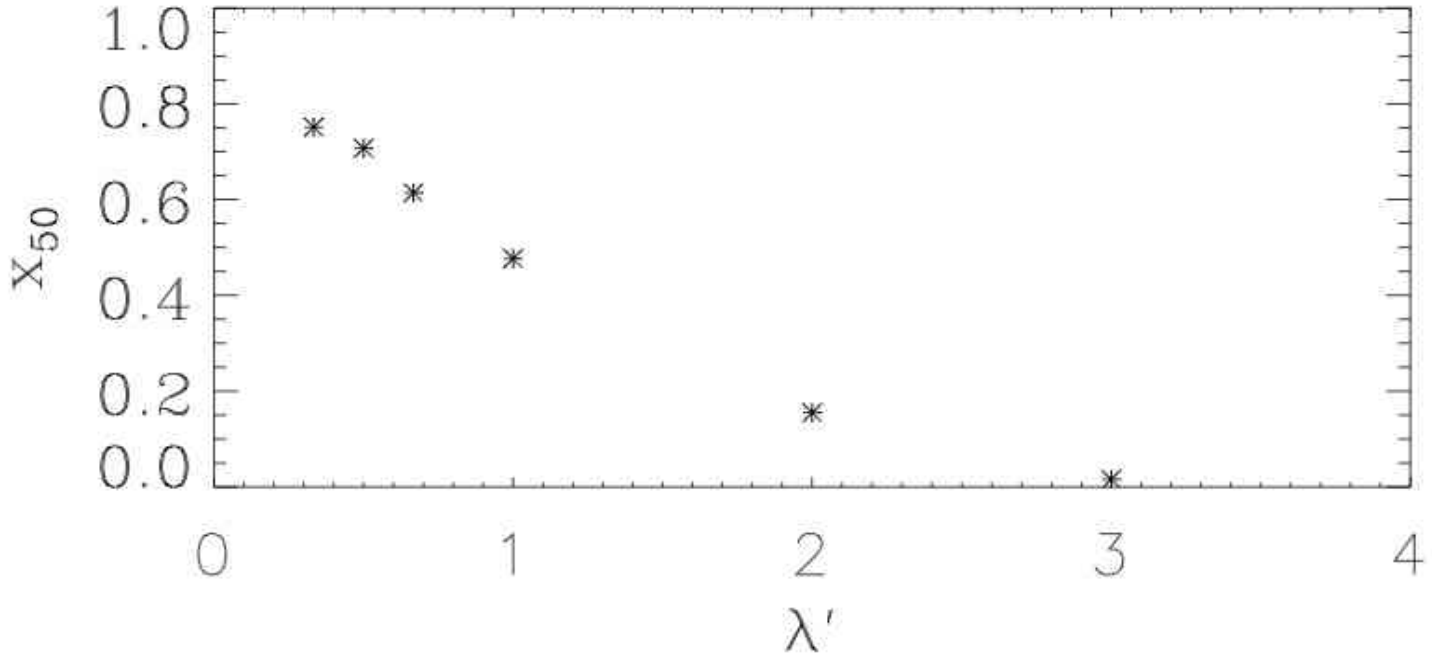




Ernst, Berczik, Just, subm.

Mass loss formula

$$\frac{t_{50}}{125\,\mathrm{Myr}} = \left[\frac{1}{50}\,\frac{N}{\ln(0.11\,N)}\right]^{x_{50}}$$



Ernst, Berczik, Just, subm.

Conclusions

- GCs are presently Roche volume underfilling (Ernst & Just 2013)
- OCs may cover both under- and overfilling regimes (Ernst & Just 2013)
- Dissolution mechanism is different in the over- and underfilling regimes (Ernst, Berczik, Just, submitted):
  - Overfilling regime: Mass-loss driven dissolution
  - Underfilling regime: Two-body relaxation driven dissolution

Thank you for your attention!

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