Gravity and Thermodynamics

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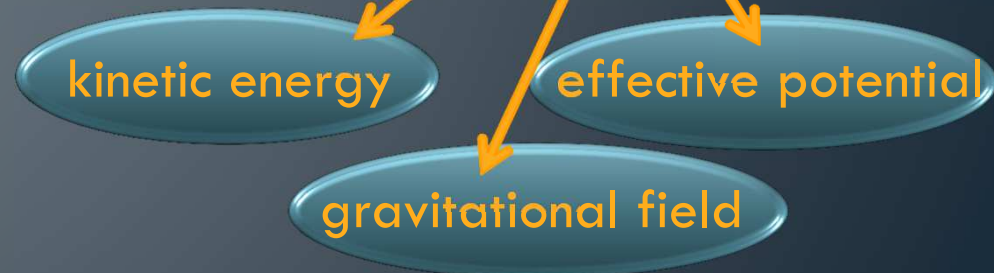# A new point of view in King function

King distribution function for Globular Clusters

$$f(\varepsilon) = \begin{cases} A\left[e^{-\frac{\varepsilon}{kT}} - e^{-\frac{\psi}{kT}}\right] & \varepsilon \leq \psi \\ 0 & \varepsilon > \psi \end{cases}$$

$$f(\varepsilon) = Be^{-H/k\theta}$$

$$H = \varepsilon + m\varphi + \phi$$

kinetic energy

effective potential

gravitational field

It is possible to include the competing effects of stellar encounters and evaporation of stars in a Boltzmann-like distribution function thanks to an effective potential ϕ, which reduces the phase space accessible to particles

Kinetic and thermodynamic variables

Kinetic variables defined using the kinetic part of the Hamiltonian

Thermodynamic variables defined using the full Hamiltonian

Intensive Variable	Extensive Conjugate
$T = R\theta$	S
$P = R\Pi$	V
$\langle \mu_0 - \varepsilon \rangle = R\langle \alpha_0 - H_0 \rangle$	N

Equation of state
$$\Pi V = Nk\theta$$
$$PV = NkT$$

First principle
$$dU = \theta dS - \Pi dV + \alpha dN + N\langle d\phi \rangle$$
$$dU_k = TdS - PdV + \langle \mu_0 \rangle dN + N(d\langle \mu_0 \rangle - \langle d\mu_0 \rangle)$$

Gibbs-Duhen relation
$$N\langle d\phi \rangle = Sd\theta - Vd\Pi + Nd\alpha$$
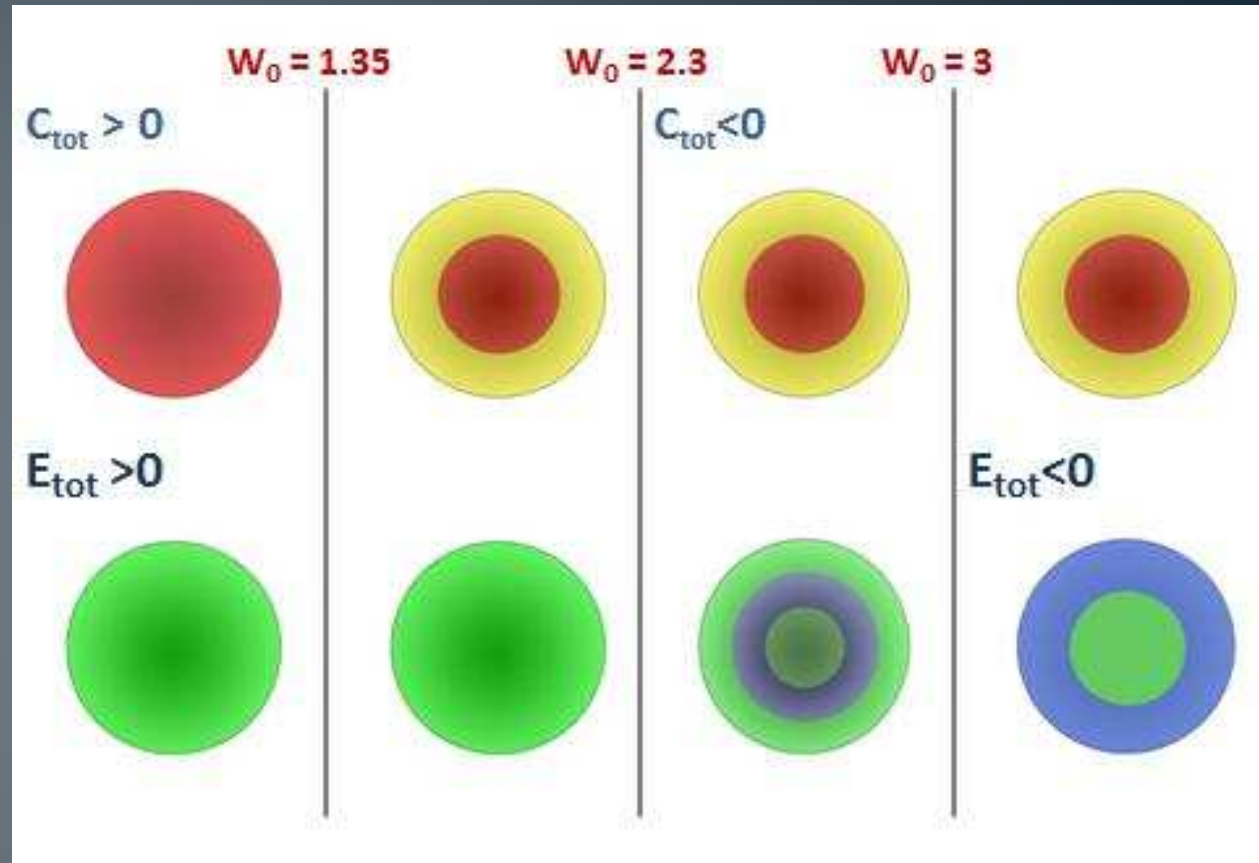$$N(d\langle \mu_0 \rangle - \langle d\mu_0 \rangle) = SdT - VdP + Nd\langle \mu_0 \rangle$$

Euler equation
$$U = \theta S - \Pi V + \alpha N$$
$$U_k = TS - PV + \langle \mu_0 \rangle N$$

Configurations and evolution

- $W_0 > 1.35$ regions with negative specific heat
- $W_0 > 2.3$ intermediate regions with negative energy
- $W_0 > 3$ negative total energy

- $W_0 < 1.35$ GCs don't evolve towards gravothermal catastrophe
- $W_0 < 3$ GCs evolve towards disruption