Structure and kinematics of tidally limited satellite galaxies in LCDM

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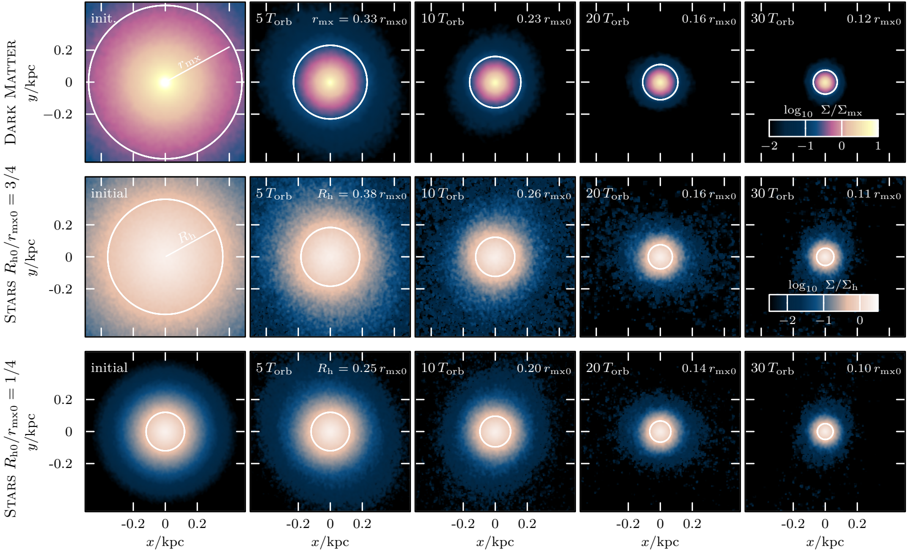


Tidal stripping of stellar tracers in NFW subhalo

Numerical setup:

- NFW subhalo, orbiting in an isothermal $220\,\mathrm{km\,s^{-1}}$ host halo
- mass-less stellar tracers, $\rho_\star \propto e^{-r/r_\star}$
- stellar probability tagging:

  $\mathcal{P}_\star(E) = (\mathrm{d}N_\star/\mathrm{d}E)/(\mathrm{d}N_\mathrm{DM}/\mathrm{d}E)$

Initial conditions:

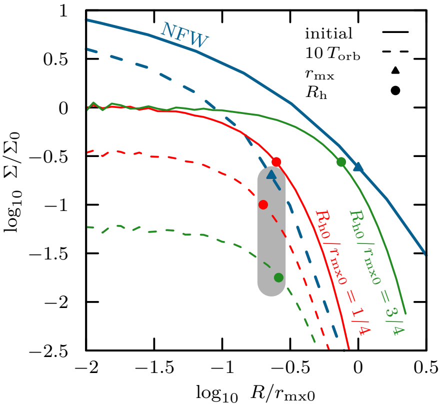
- two tracers with initial 2D half-light radii of

  tracer a: $R_\mathrm{h0}/r_\mathrm{mx0} = 3/4$

  tracer b: $R_\mathrm{h0}/r_\mathrm{mx0} = 1/4$

Evolved system:

- $R_\mathrm{h} \sim r_\mathrm{mx}$
- dark matter: $M_\mathrm{mx}/M_\mathrm{mx0} = 6\,\%$
- tracer a: $L/L_0 = 1\,\%$
- tracer b: $L/L_0 = 23\,\%$



Stripping of the dark matter: circular velocity

Circular velocity profiles

- $V_c = \sqrt{GM(<r)/r}$

Convergence of the density profile towards an exponentially truncated cusp

- $\rho_{asy}(r) = \rho_s \; \dfrac{e^{-r/r_s}}{r/r_s}$

Tidal evolution stalls once the subhalo crossing time

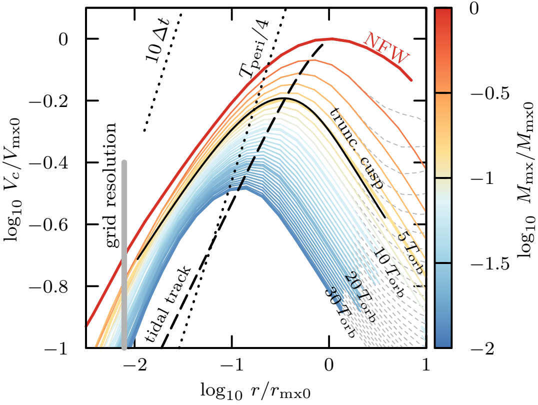
- $T_{mx} = 2\pi \; r_{mx}/V_{mx}$

equals 1/4 of the host crossing time at pericentre

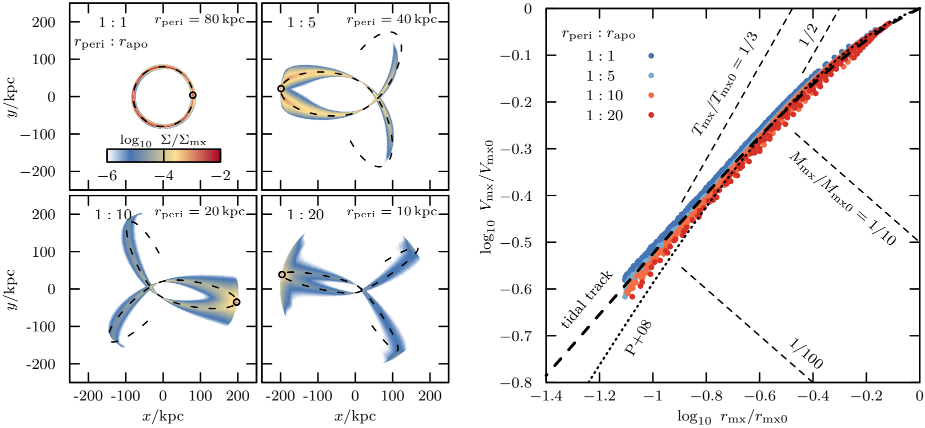
- $T_{peri} = 2\pi \; r_{peri}/V_c(r_{peri})$
- $T_{mx,asy} = T_{peri}/4$

Structural parameters follow *tidal track*

- $\dfrac{V_{mx}}{V_{mx0}} = \dfrac{2^\alpha (r_{mx}/r_{mx0})^\beta}{[1+(r_{mx}/r_{mx0})^2]^\alpha}$



Stripping of the dark matter: tidal tracks



(EN21, arXiv:2011.07077)

Energies referred to potential minimum (ground state)

- $\mathcal{E} \equiv 1 - E/\Phi_0$

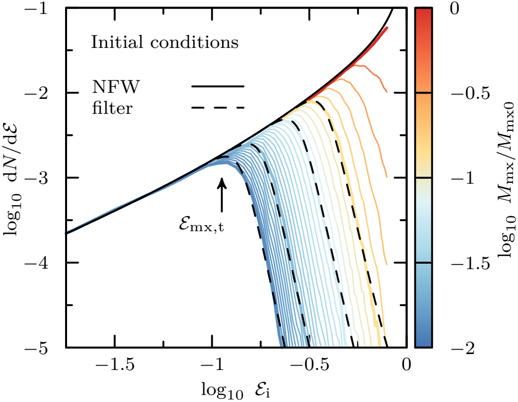
Most bound: $\mathcal{E} = 0$. Unbound: $\mathcal{E} \geq 1$. Potential minimum correlates with $V_{\rm mx}$

- NFW: $\Phi_0 \approx -4.63\ V_{\rm mx}^2$
- truncated cusp: $\Phi_0 \approx -3.35\ V_{\rm mx}^2$

Tides truncate sharpy in $\mathcal{E}$. Those particles with smallest $\mathcal{E}$ form the bound remnant.

- $\left.\frac{\mathrm{d}N}{\mathrm{d}\mathcal{E}}\right|_{\rm i,t} = \left.\frac{\mathrm{d}N}{\mathrm{d}\mathcal{E}}\right|_{\rm i} \left[1 + (a\ \mathcal{E}/\mathcal{E}_{\rm mx,t})^k\right]^{-1}$ (with $k \approx 12$, $a \approx 0.85$)

Tidal truncation energy $\mathcal{E}_{\rm mx,t}$ correlates with remnant mass $M_{\rm mx}/M_{\rm mx0}$



Stripping of the dark matter: initial conditions

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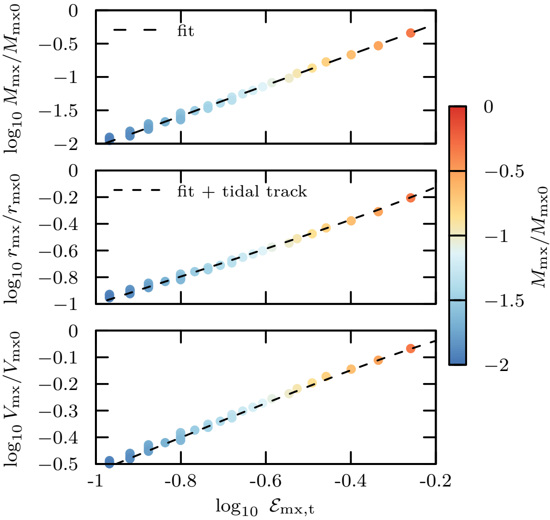
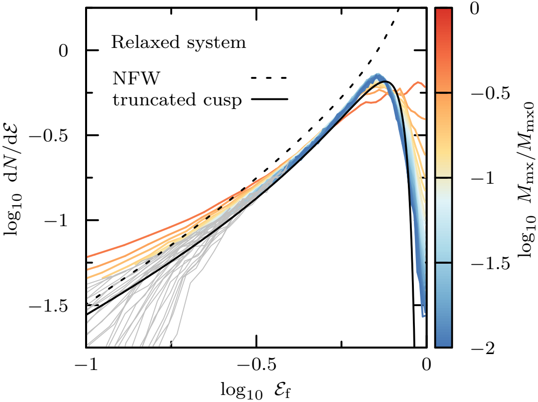


Stripping of the dark matter: relaxed system

Convergence of the density profile towards an exponentially truncated cusp

- $\rho_{\rm asy}(r) = \rho_s \ \dfrac{e^{-r/r_s}}{r/r_s}$
- energy distribution has well-defined maximum
- profile converged once $M_{\rm mx}/M_{\rm mx0} \lesssim 1/10$



Stripping of the dark matter: Initial-to-final energy mapping

Energy: normalised to instantaneous potential minimum

- $\mathcal{E}_\mathrm{i} = 1 - E/\Phi_{0,\mathrm{i}}$
- $\mathcal{E}_\mathrm{f} = 1 - E/\Phi_{0,\mathrm{f}}$

Universal energy mapping, form independent of $M_\mathrm{mx}/M_\mathrm{mx0}$

- $\bar{\mathcal{E}}_\mathrm{f} = \left[1 + a\left(\mathcal{E}_i/\mathcal{E}_\mathrm{mx,t}\right)^{-b}\right]^{-1/b}$

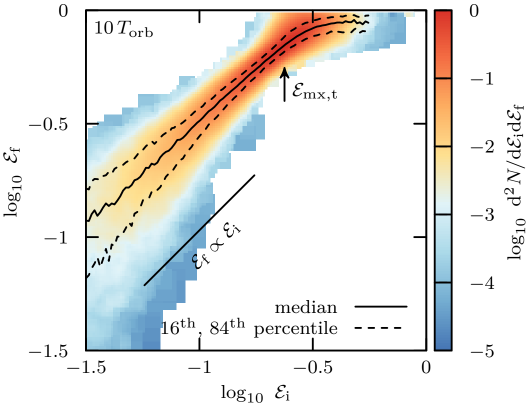
Energy map preservers most-bound energy distribution

- $\mathcal{E}_\mathrm{i} < \mathcal{E}_\mathrm{mx,t}$: $\bar{\mathcal{E}}_\mathrm{f} \propto \mathcal{E}_\mathrm{i}$

The final energy distribution may be empirically constructed through

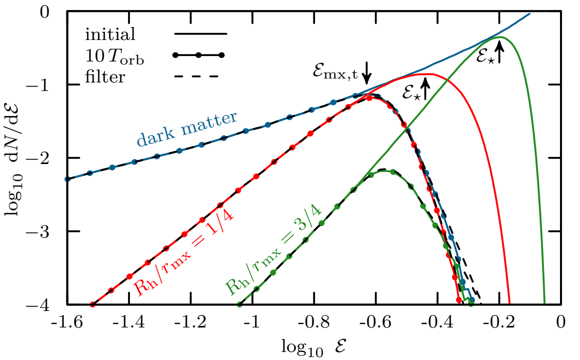
- $\left.\frac{\mathrm{d}N}{\mathrm{d}\mathcal{E}}\right|_\mathrm{f} = \left.\frac{\mathrm{d}N\left(\bar{\mathcal{E}}_f^{-1}(\mathcal{E}_f)\right)}{\mathrm{d}\mathcal{E}}\right|_\mathrm{i,t} \left|\frac{\mathrm{d}\bar{\mathcal{E}}_f^{-1}}{\mathrm{d}\mathcal{E}_f}\right|$,

or, to take into account the scatter, through a convolution.



Stripping of stars: energy cut imposed by tides

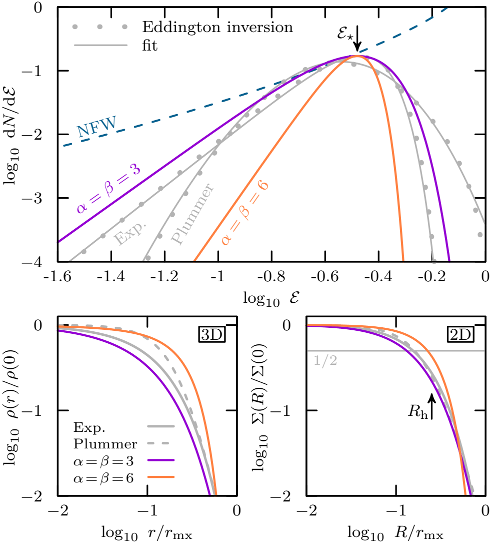
- same filter function as for dark matter
- luminosity only affected if tidal truncation within stellar energy range
- *tidally limited* regime: peak energy $\mathcal{E}_{\rm mx,t}$ similar for dark matter and stars



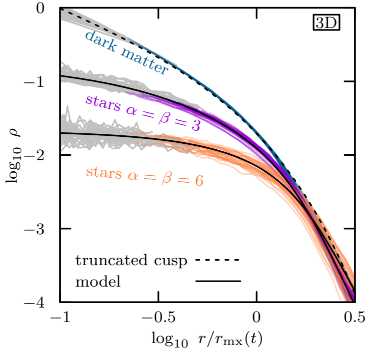
initial conditions

Stripping of stars: tidally limited regime

Initial conditions



Relaxed system

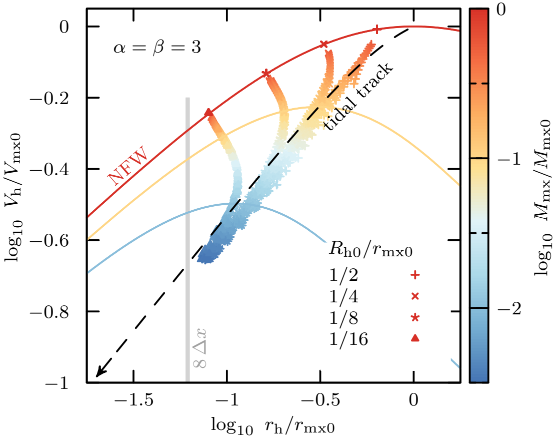


initial $\mathrm{d}N_\star/\mathrm{d}\mathcal{E} =$

$$\begin{cases} \mathcal{E}^\alpha\ \exp\left[-(\mathcal{E}/\mathcal{E}_\star)^\beta\right] & \text{if } 0 \le \mathcal{E} < 1 \\ 0 & \text{otherwise} \end{cases}$$

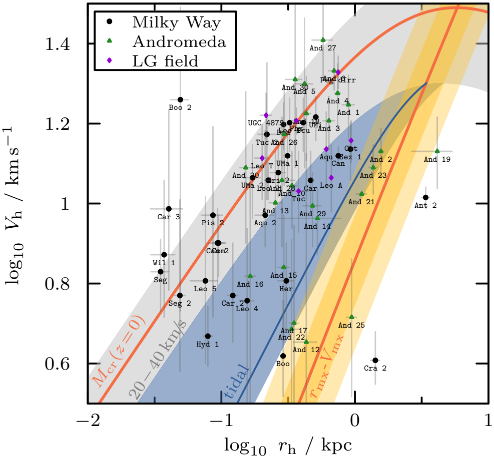
Stripping of stars: tidal tracks

- 3D half-light radius r_{h} vs. circular velocity V_{h} at that radius
- four stellar tracers with different initial segregation: $R_{\mathrm{h0}}/r_{\mathrm{mx0}} = 1/2$, $1/4$, $1/8$, $1/16$
- no unique track: deeply segregated systems expand first, more extended ones get trimmed down immediately
- evolution asymptotic to dark matter $r_{\mathrm{mx}}, V_{\mathrm{mx}}$ - track



Cosmological context: comparison against Local Group dwarfs

- Shown are LG dwarfs with $L < 10^7 \mathrm{L}_\odot$
- grey band: $20 < V_{\mathrm{mx}}/\mathrm{km\,s^{-1}} < 40$
  NFW: subhalos massive enough to form stars
- yellow band: cosmological mass-concentration relation
- blue area (this work): region accessible through tides
- structure of low-density dwarfs like Ant 2 and Cra 2 can't be explained by tides alone
- **to be submitted soon:**
  Asya's detailed analysis of Cra 2 (MW-like host, Gaia orbit, cosmological mass/size/luminosity)



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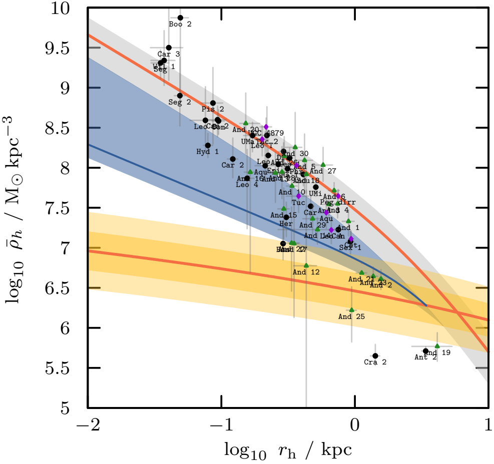

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