

# Cosmological simulations of the Milky Way

Lucio Mayer

Institute for Theoretical Physics, University of Zurich, Wintherturstrasse 190, Zurich (CH)

**Abstract.** Recent simulations of forming low-mass galaxies suggests a strategy for obtaining realistic models of galaxies like the Milky-Way.

---

Cosmological simulations of galaxy formation are powerful tools for confronting the  $\Lambda$ CDM model with observational datasets. The increase in mass and spatial resolution and the improvement of sub-grid algorithms for star formation and feedback processes have recently resulted in simulated galaxies with realistic disk size and angular momentum content (Mayer *et al.* 2008; Governato *et al.* 2009a). However, simulated galaxies hosted in halos with masses  $\sim 10^{12} M_{\odot}$  exhibit prominent bulges and structural parameters reminiscent of Sa spirals rather than of Sb/Sc galaxies. Surface densities at the solar radius are larger than that of the Milky Way (MW) by factors of a few and the more massive bulge produces a steeper rotation curve compared to that of the MW (Read *et al.* 2009). At halo masses  $M_{\text{vir}} > 2 \times 10^{12} M_{\odot}$  the predominance of hot-mode gas accretion counters the presence of a prominent star forming disk at  $z = 0$ , producing earlier-type objects resembling S0 galaxies (Brooks *et al.* 2009) and supporting recent estimates based on RAVE that yield  $M_{\text{vir}} \sim 10^{12} M_{\odot}$  (Smith *et al.* 2007).

Yet the solution to forming a realistic MW analog could be at hand. Recently we have performed galaxy-formation simulations for mass scales  $< 10^{11} M_{\odot}$ . By sampling these low-mass galaxies with several millions of particles, we achieve a mass resolution better than  $10^3 M_{\odot}$  in the baryons, thus resolving individual molecular clouds. Star formation can now be tied to gas at molecular cloud densities ( $\rho > 100 \text{ cm}^{-3}$ ). A realistic, inhomogeneous interstellar medium is obtained that results naturally in stronger supernova outflows than when the standard star formation threshold ( $\rho = 0.1 \text{ cm}^{-3}$ ) is adopted. Such outflows efficiently remove the low-angular momentum baryonic material from the central region, suppressing the formation of a bulge and producing an object with a slowly rising rotation curve in very close agreement with observed dwarf galaxies (Governato *et al.* 2009b; see also Ceverino & Klypin 2009). We argue that comparable resolution of MW-sized galaxies will yield rotation curves and bulge-to-disk ratios appropriate for Sb-Sc spirals at  $z = 0$ . This requires increasing the number of particles employed by more than an order of magnitude.

## References

- Brooks, A. M., Governato, F., Quinn, T., Brook, C. B., & Wadsley, J., 2009, *ApJ*, 694, 396  
Ceverino, D. & Klypin, A., 2009, *ApJ*, 895, 292  
Governato, F., Brook, C. B., Brooks, A. M., Mayer, L., Willman, B., Jonsson, P., Stilp, A. M., Pope, L., Christensen, C., Wadsley, J., & Quinn, T., 2009a, *MNRAS*, 398, 312  
Governato, F., Brook, C. B., Brooks, A. M., Mayer, L., Willman, B., Jonsson, P., Stilp, A. M., Pope, L., Christensen, C., Wadsley, J., & Quinn, T., 2009b, *Nature* in press (arXiv:0911.2237)  
Mayer, L., Governato, F., & Kaufmann, T., 2008, *Adv. Sci. Lett.*, 1, 7  
Read, J., Mayer, L., Brooks, A.M., Governato, F., & Lake, G., 2009, *MNRAS*, 397, 44  
Smith, A., *et al.*, 2007, *MNRAS*, 379, 755