The angular momentum of dark halos : merger and accretion effects

S. Peirani, R. Mohayaee and J.A. de Freitas Pacheco

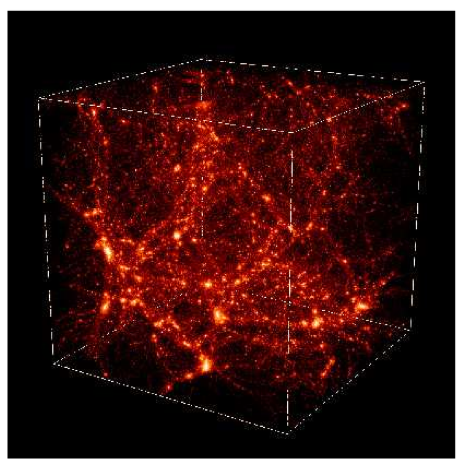
astro-ph/0311149

email: peirani@obs-nice.fr

Observatoire de la Côte d'Azur

Abstract

We present new results on the angular momentum evolution of dark matter halos. Halos, from N-body simulations, are classified according to their mass growth histories into two categories: the *accretion category* contains halos whose mass has varied continuously and smoothly, while the *merger category* contains halos which have undergone sudden and significant mass variations (greater than 1/3 of their initial mass per event). We find that the angular momentum grows in both cases, well into the nonlinear regime. For individual halos we observe strong correlation between the angular momentum variation and the mass variation. The rate of growth of both mass and angular momentum has a characteristic transition time at around $z \sim 1.5 - 1.8$, with an early fast phase followed by a late slow phase. Halos of the merger catalog acquire more angular momentum even when the scaling with mass is taken into account. The spin parameter has a different behavior for the two classes: there is a *decrease* with time for halos in the accretion catalog whereas a small *increase* is observed for the merger catalog. When the two catalogs are considered together, no significant variation of the spin parameter distribution with the redshift is obtained. We have also found that the spin parameter neither depends on the halo mass nor on the cosmological model.



1. Simulation

The N-body simulation analyzed uses adaptive particle-particle/particle-mesh (AP^{3}M) code HYDRA (Couchman, Thomas & Pearce 1995). We ran a ΛCDM simulation with $h = 0.65$, $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$ and $\sigma_8 = 0.9$. The simulation was performed in a periodic box of side $30h^{-1}$ Mpc with 256^3 particles (hence with mass resolution of 2.051×10^8 M$_\odot$). The simulation started at $z = 50$ and ended at the present time $z = 0$.

Halo catalogs at different redshifts were prepared by using a friends-of-friends (FOF) algorithm (Davis et al. 1985), with a linking length of b = 0.15 in units of the mean interparticle separation. Once a structure is identified, the total energy of each particle is computed, with respect to the centre of mass, and those with positive energy are removed. The procedure is repeated with the new centre of mass, computed according to its usual definition, until no unbound particles are found.

We have identified 8728 halos at $z = 0$ and out of this number we have prepared a sample of 780 halos which have never undergone a major merger event, and their mass have always increased by accretion or by capture of small lumps of matter. We also selected 561 halos which had at least one major merger episode in their history, corresponding to an increase of their masses at least by a factor of $1/3$ in the event. Since this limit, generally adopted in the literature is rather arbitrary, we have also examined how our results are modified if we decrease the above *mass-fraction threshold* to $1/6$.

2.Angular Momentum Evolution

In spite of the erratic variations of the spin when individual halos are considered, on the average, an increase of the angular momentum is observed for both samples. Fig. 1 shows the median value of angular momentum distribution, $\mathrm{med}(\log J)$, as a function of time. Two scaling regimes are noticed with a characteristic redshift of $z \sim 1.5 - 1.8$.

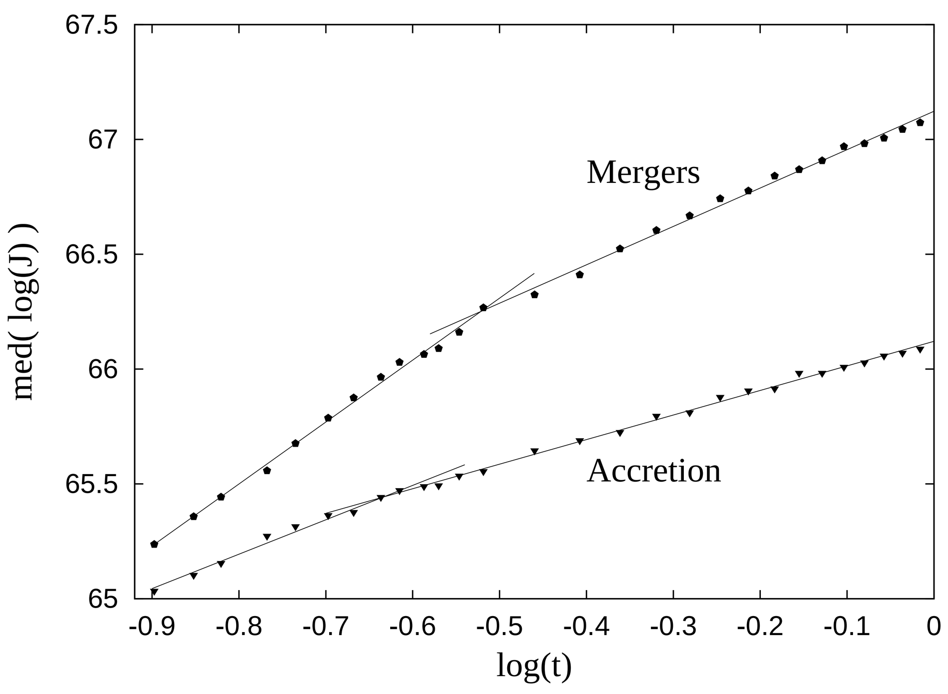


Figure 1: The evolution of the median of the logarithm of the angular momentum, $\mathrm{med}(\log J)$, with time for the halos which grow by accretion and halos which have undergone at least one merger. The growth continues well after the first shell-crossing time which is at about $z \sim 6$ ($t \sim 0.065/H_0$).

A best fit to the data shows that :

$$J_{acc} \propto \begin{cases} t^{1.50} \text{ for } z > 1.8 \\ t^{1.07} \text{ for } z < 1.8 \end{cases} \qquad J_{mer} \propto \begin{cases} t^{2.70} \text{ for } z > 1.5 \\ t^{1.67} \text{ for } z < 1.5 \end{cases}$$

In the redshift interval $3.5 > z \geq 0$, the average angular momentum grows by a factor of 80, suggesting clearly that merging transfer angular momentum much more efficiently than accretion. In fact, since the angular momentum scales with mass as $M^{5/3}$ and halos which have grown by merging are more massive, this effect must be taken into account when comparing both samples. In this case, it is more convenient to compare the distribution of the quantity $\log(J/M^{5/3})$. In Fig. 2 the distributions for the two samples at $z = 0$ are compared and one can see that merging events give a larger contribution to the final angular momentum of halos irrespective of the mass variations.

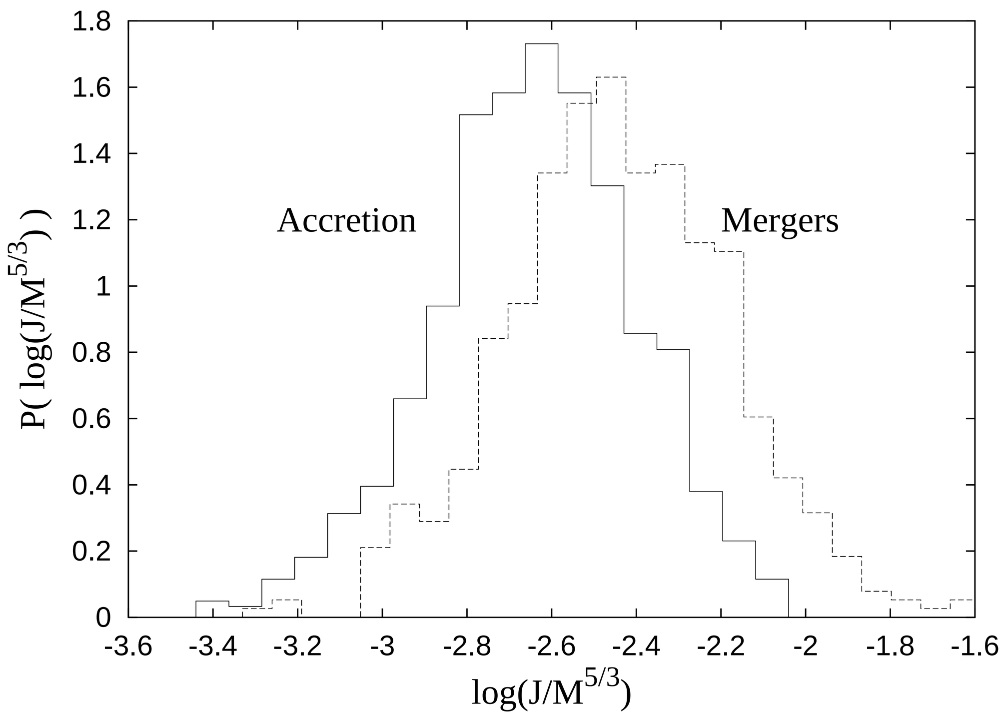


Figure 2: The distribution of the angular momentum, normalized by $M^{5/3}$. The mean of the distribution is larger for halos which have undergone major merger events.

3. The evolution of the spin parameter

Previous works have shown that the spin parameter λ, obtained from simulations, has a log-normal distribution (Barnes & Efstathiou 1987; Cole & Lacey 1996; van den Bosch 1998; Ryden 1998),

$$P(\lambda)d\lambda = \frac{1}{\sigma_\lambda\sqrt{2\pi}} exp\left(-\frac{ln^2(\lambda/\lambda_0)}{2\sigma_\lambda^2}\right)\frac{d\lambda}{\lambda} \qquad (1)$$

which seems to be a universal result, independent of the cosmological model. In Fig. 3 we show the distribution of the spin parameter at $z = 0$ for the two catalogs considered here. An inspection of this plot confirms again that halos which have undergone important merger episodes have, on the average, a larger spin parameter and a wider distribution than those evolved by accretion only.

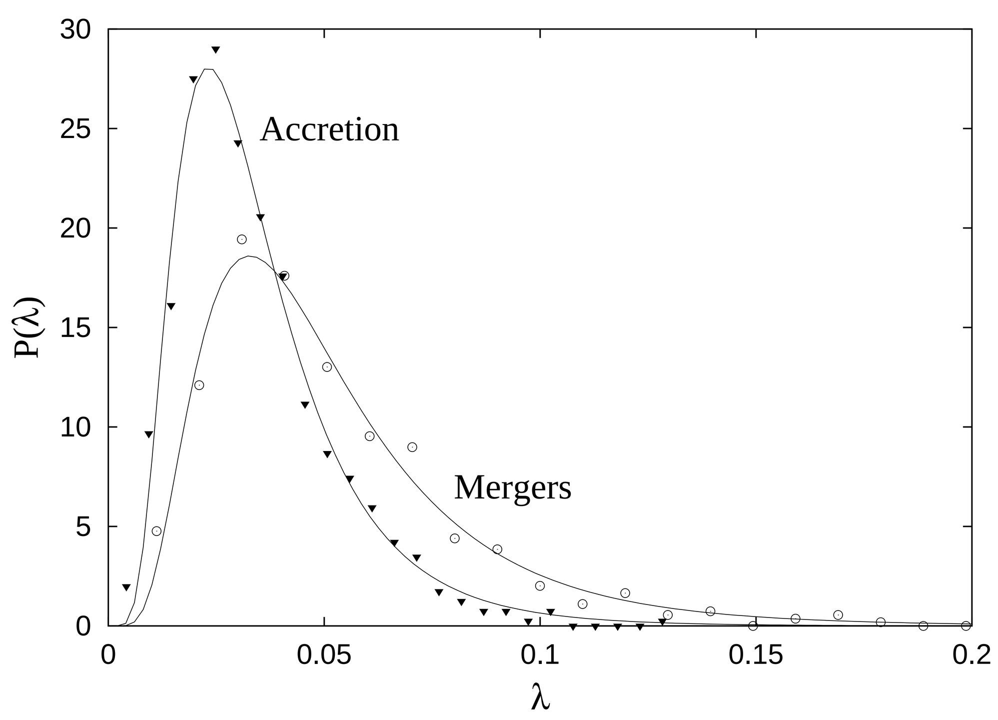


Figure 3: The distribution of the spin parameter for halos that grow by merger and those which grow by accretion at $z = 0$.

Earlier investigations of the evolution of the spin parameter indicate that its distribution does not vary with redshift. This result seems to be valid both in the TTT and in the random walk capture model (Vitvitska et al. 2002). In Fig. 4 we plot statistical parameters of the λ distribution, as the mean, median and λ_0, as a function of the redshift, when the halos of each catalog separately and also both catalogs together are considered (1341 halos).

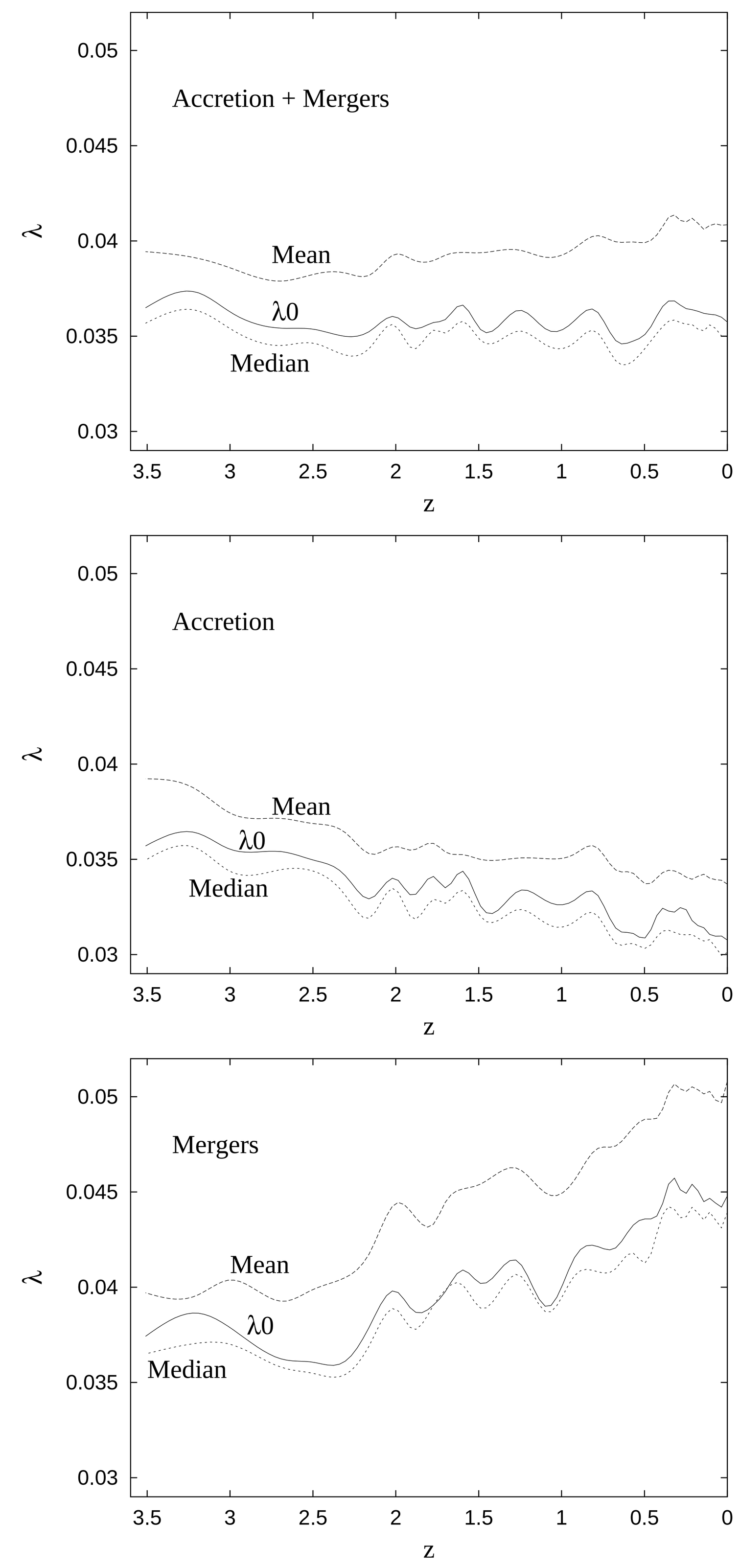


Figure 4: Panels from up to down: a) evolution of the spin parameter for all the halos (accretion + merger). Three statistical parameters are shown: the median, the mean and λ_0; evolution of the same parameters but for halos of the accreting catalog only (b) and for halos of the merger catalog (c).

This figure demonstrates that, in spite of some erratic fluctuations, the variations in both λ_0 and the median are quite small, although a slight increase seems to be suggested by the evolution of the mean value. Taken at the face value, these results are compatible with no variation of λ with z or, at least compatible with a slight increase in the mean. However, the results are quite different if we analyze the evolution of the spin parameter for the two samples (accretion and merger) independently. The middle and the lower panels of Fig. 4 show respectively the evolution of the same statistical parameters for halos evolved only by accretion and those which have had at least one major merger event. We notice a clear and significant evolution in opposite senses: halos evolved by accretion have a *decreasing* spin parameter, whereas for halos evolved by merging λ *increases*. Typical values for the rmsd of the mean value of the spin parameter λ are 0.02.

†Address for correspondence: Department Fresnel, CNRS-UMR 6528, BP 4229, F-06304 Nice Cedex 4, France