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A new probe of dark energy

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Despite the many successes of concordance ÎCDM cosmology, increasingly accurate cosmological datasets are starting to reveal tensions. In such a landscape, ones attention naturally shifts towards new avenues to probe cosmology. The turnaround scale, defined as the scale separating gravitationally bound structures from the Hubble flow, has properties that make it a promising cosmological probe (a) the matter enclosed by the turnaround radius has a characteristic average matter density (the âturnaround densityâ, Ïta) which is the same for structures of all masses at a given cosmic epoch. This means that for present cosmic epoch and for concordance cosmological parameters (Î©m â¼ 0.3, Î©Î â¼ 0.7) turnaround structures exhibit a density contrast with the matter density of the background Universe of Î´ â¼ 11. (b) The value of Ïta and its evolution with cosmic time depends on (and probes) the cosmological parameters Î©m and Î©Î. Although the behaviour of matter on the turnaround scale is well studied under the assumption of spherical symmetry, it is by no means a priori obvious that the properties that render it cosmologically interesting also survive in highly non-spherical realistic structures. To this end, we use N-body simulations of different cosmologies to examine whether a characteristic turnaround radius can be meaningfully identified for galaxy clusters in the presence of full three-dimensional effects. In particular, we show that by analysing radial velocity profiles around collapsed structures, extending out to many times the overdensity radius R200, one can unambiguously identify the turnaround radius as the largest non-expanding scale around the center of a cluster. We, also find that for halos of masses M > 10ˆ13 Msun, the turnaround radius Rta scales with the enclosed mass M as Mˆ1/3, as predicted by the spherical collapse model. This means that halos indeed exhibit a characteristic average density within the turnaround scale. Finally, we discuss the deviation of Ïta in simulated halos from its theoretical prediction and relate it to halo deviations from spherical symmetry.

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