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USING VORONOI TESSELLATIONS TO IDENTIFY GROUPS IN N-BODY SIMULATIONS

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RESUMEN

Usamos teselaciones de Voronoi para identificar estructuras en simulaciones cosmológicas hidrodinámicas de N-cuerpos, las cuales contienen materia oscura, gas y estrellas. Ésta es una técnica adaptiva que permite estimaciones precisas de la densidad y el gradiente de densidad, para una distribución no uniforme de puntos. Discutimos como estas estimaciones nos permiten identificar estructuras en halos de materia oscura, y en estrellas para identificar galaxias, y como esto es en algunos casos mejor que FOF u otros métodos sofisticados como SubFind. La naturaleza adaptiva de esta técnica nos permite considerar gradientes a grandes escalas, permitiendo la identificación de una galaxia en un fondo de densidad alto. El método resuelve estructuras con diversos perfiles de densidad como las galaxias espirales o irregulares, y no usa ninguna cota gravitacional para verificar si las estructuras están ligadas o virializadas, esto es bueno para identificar estructuras en evolución que no están necesariamente en equilibrio.

ABSTRACT

Here we use Voronoi tesselations to identify structures in hydrodynamical cosmological N-body simulations, that contain dark matter, gas and stars. This is an adaptive technique that allows accurate estimates of densities, and density gradients, for a non-structured distribution of points. We discuss how these estimates allow us to identify structures in the dark matter haloes, and in the stars, to identify galaxies, and how it is better than FOF or other sophisticated methods such as SubFind in some cases. The adaptive nature of the technique allow us to take large-scale gradients into account, allowing the identification of a galaxy on top of a background. The method resolves structures with multiple density profiles like spiral or irregular galaxies, and does not use any gravitational constraint to verify if structures are bound or virialized, so it is good for identifying evolving structures that are not necessarily in equilibrium.

Key Words: galaxies: structure — large-scale structure of universe — methods: n-body simulations

1. INTRODUCTION

Increasing number of DM n-body simulations which also includes gas and stars particles are becoming more popular, instead of simulations only taking into account dark matter particles. Current cluster/halo finders like FOF or Subfind have proven to work fine when identifying structures in DM which are usually distributed as King or NFW profiles, but for stellar or gas structures they are not enough.

The Voronoi tessellation (Voronoi 1908, hereafter VT) technique is one of the best adaptive methods to recover a precise density field from a discrete particle distribution in comparison with SPH or other interpolation based techniques (Pelupessy et al. 2003).

VT was first used in astrophysics (Kiang 1966). The application of Voronoi tessellations to the distribution of galaxies started with Icke & van de Weygaert (1987). In large scale structures (Zaninetti 1991; Pierre 1990; van de Weygaert & Babul 1994) and cluster finding follows Ramella et al. (2001); Panko & Flin (2006); Marinoni et al. (2002); Neyrinck et al. (2005).

2. METHOD

In our method we make use of VT properties to estimate the density gradient field in addition to the density field, and we use voronoi vertices in common between neighbor particles to group in a fast way particles inside and outside a structure. We leave as free parameter a density gradient threshold to define the minimum contrast above the background for the structures we want to identify, which is an improvement over density tresholds or linking lenghts, allowing a wide range of environments for detections, without any gravitational constraint (detailed description in Gonzalez et al., in preparation). The method is implemented in the software SFVT, and can be found in `http://www.astro.puc.cl/~regonzar`, with full documentation and samples.

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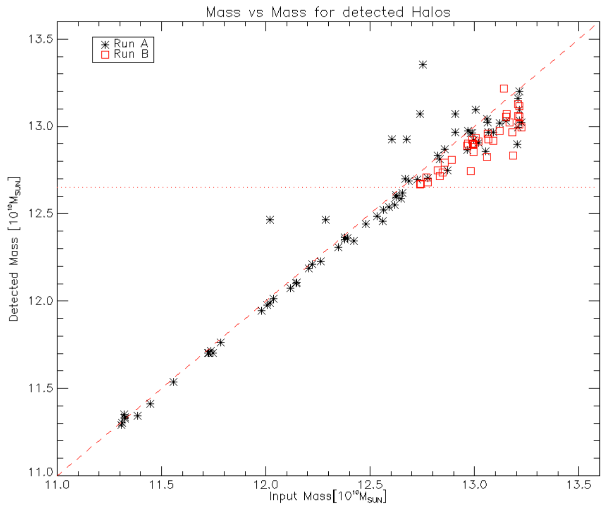

Fig. 1. Input mass and recovered mass relation for all halos.

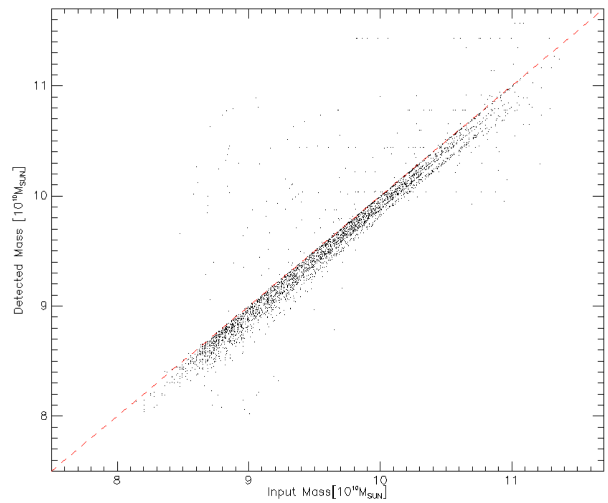

Fig. 2. Input mass and recovered mass relation for all recovered galaxies.

3. TESTING

We made several test to study the best parameters for the method and its limitations. First we use the method to recover randomly distributed DM NFW halos from a Monte-Carlo simulation, and run SFVT with 2 set of parameters. In Figure 1 is shown the recovered vs input mass plot for all detected halos, in one set of parameters (starred points) we recover 99% of galaxies but with a spread in mass recovery for high masses halos, in the second set of parameters intended for massive halos we recover all halos with 90–100% mass recovery, but we set a minimum mass threshold because the detection becomes poor at low masses.

In the second test we take a realistic distribution of stellar particles, galaxy positions and masses extracted from a semianalitic simulation GALFORM and particle distribution following galaxies with random bulge/disk ratios and orientations. We run sfvt and in Figure 2 we can see the input/output mass relation for galaxies, 90% galaxies were recovered but the total mass of each galaxy es better recovered than for NFW profiles. Irregular galaxies are not covered in this analisys, but they are in the same range of masses, density and gradients, but with strange shapes and SFVT should have no problems with this.

4. CONCLUSION

In comparison with FOF linking lenght, the gradient density threshold has a more interesting free parameter with a more applicable physical meaning. This method allow identify structures embedded in a wide range of environments independent of its shape, even in merged structures or sub-structures. Also it resolve structures with multiple density profiles like spiral galaxies, but requires a fine tunning of the input parameter to recover specific types of structures in each run. This method recover better shapes for structures since the VT is the best way to estimate density and density gradient at a given point in the sample, so it guarantees that no smooth (like SPH kernel) will bias the method specially in scales of the softening lenght of the simulation. Also, it does not use any gravitational constrain to verify if structures are bounded or virialized, so it is good for identifying evolving not in equillibrium structures. SFVT require only position of particles, so it is easy to apply to real data.

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