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THE MASS POWER SPECTRUM AT SUB-GALACTIC SCALES AS A CONSTRAINT TO DARK MATTER PROPERTIES

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RESUMEN

Exploramos posibles cotas a la amplitud del espectro de potencias de la materia oscura, a escalas sub-galácticas, con la finalidad de poner a prueba propiedades de las partículas candidatas a formar la materia oscura. Presentamos estudios preliminares, en términos de la sensibilidad de la dinámica del Sistema Solar y de la presencia de binarias abiertas en galaxias dSph.

ABSTRACT

We explore the possible constraints to the dark matter (DM) mass power spectrum amplitude at sub-galactic scales, with the aim to test the properties of DM particle candidates. We present preliminary results discussing the sensitivity of Solar System dynamics and dSph's wide binaries abundance to the small scale DM distribution. We also discuss possible future avenues.

Key Words: dark matter — galaxies: halos

1. INTRODUCTION

The LCDM cosmological scenario is consistent with the large scale Universe, however one of the main ingredients, the Dark Matter, has not yet been detected. One of the principle uncertainties is the distribution of the DM at the scales where the detectors works (Green 2010). Specifically models based on WIMP DM predict a large abundance sub-structure at sub-galactic scales, this has been considered as a potential problem for the LCDM scenario because is not obvious that the substructure has an observational counterpart (Klypin et al. 1999, see however Xu et al. 2010). The sub-structure abundance is related with the spectrum of primordial fluctuations, the nature of the dark matter and the dynamical evolution of the smallest fluctuations. The LCDM model fix the fluctuation spectrum and the dynamical evolution is studied trough N-body simulations, so the properties of this spectrum at sub-galactic scales can constitute a test for the nature of the DM particle: it has been shown that the mass and self-annihilation of the neutralinos set the cut off at approximately $10^{-4} - 10^{-6}\ M_\odot$ (Green et al. 2004), while the characteristics of the Axion DM could set the cut off down to the $10^{-15}\ M_\odot$ (Johnson & Kamionkowski 2008), for instance. Other DM candidates like the Warm Dark Matter are also consistent with the large scale but they predict a PS cut off at approximately dwarf galaxies mass (Colín et al. 2000). Once an specific DM particle is assumed, the survival of the smallest structures its by itself a topic of discussion, being the extrapolation from N-body simulations at larger scales and the semi-analytic models the tools we have to estimate the amount of substructure that should be present today (Diemand et al. 2005; Angulo & White 2010).

In § 2 we explore a complementary strategy that allow us to set upper limits to the the existence of the dark small structure –microhalos and streams– in the Galactic halo. Since the orbital elements of planets are known with outstanding accuracy (Pitjeva 2005) and the increasing precision in the measurement of the earth-moon distance (Murphy et al. 2008), the Solar System might be sensitive to dynamical perturbations triggered by dark matter substructure, subject to its abundance and internal properties. Extensions of this method can be applied to the stability of the Kuiper belt and for wide binary stars abundance (González-Morales 2011, in preparation).

2. SOLAR SYSTEM CONSTRAINTS

We model the interaction between an specific planetary orbit and a population of microhalos (or streams). Our first approximation is to consider spherical rigid microhalos and calculate the impulsive energy injection to the orbit (Binney & Tremaine 2008). Our second approach is to consider microhalos that has been disrupted by tidal

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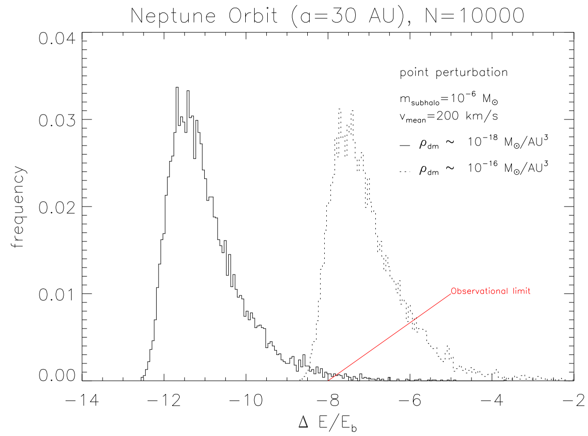

Fig. 1. Energy perturbation due to encounters with subhalos on to the Neptune's orbit for the standard value of local DM density(solid)(Green 2010) and for two orders of magnitude higher(dashed).

forces, and we model them as *streams* of cylindrical symmetry (González-Morales 2011, in prep.). As an illustration we present the case of Neptune's orbit. In Figure (1) we show a Montercalo realization over the perturber-planet impact parameter and relative velocity distributions, assuming the spherical mass approximation, for two different values of the local DM density. Our halo and subhalos parameters are motivated by larger scale N-body simulations that assumes a neutralino power spectrum. The histogram shows the fraction of possible Solar System-substructure encounter histories corresponding an energy injection $\Delta E/E$ over 4 Gyr, approximately the Solar System age. It can be notice that the most important parameter is the amount of DM in the local neighborhood, an uncertainty quantity. This study can be seen as an upper limit for the local DM density if one assumes that neutralinos conform the DM. On the other hand, if local DM density were determined with high accuracy and its value changes significantly from the actual value, then our method would be enough to put a strong constraint on the cut-off of the mass power spectrum, with Solar System information only.

3. CONCLUSIONS AND FUTURE WORK

Although we have only presented the case for Neptune's orbit constraints on dynamical perturbation triggered by dark matter substructure, the same can be applied to Earth-Moon's orbit, were accuracy of orbital elements is even higher. As we mentioned this can be applied also to study the existence of wide stellar binaries in dSphs, which according to some authors should be in disagreement with the DM hypothesis (Hernandez & Lee 2008; Peñarrubia et al. 2010). We are applying the formalism expecting to show either of (1) catastrophic encounters are sufficient enough and disrupt the wide binaries (Peñarrubia et al. 2010) (2) dominant encounters are diffusive but they are sufficient enough to disrupt the binaries or (3) the effect of the dynamical friction due to DM that is not bound in substructure (Hernandez & Lee 2008) in conjunction with the diffusive encounters allows the existence of the wide binaries. The first two scenarios implies that the existence of wide binaries are not consistent with the existence of DM substructure as the cold DM predicts, and warm DM could be a better option, or any other candidate with a power spectrum cut-off at sub-galactic scales. Independent additional constraint to the DM power spectrum could be obtained from the high redshift 21-cm power spectrum, fluctuations in gravitational lensing images and searches of low mass galaxies in the nearby Universe. We are currently making predictions for some of those future experiments (González-Morales 2011, in prep.).

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REFERENCES

Angulo, R. E., & White, S. D. M. 2010, MNRAS, 401, 1796
Binney, J., & Tremaine, S. 2008, Galactic Dynamics (Princeton: Princeton Univ. Press)
Colín, P., Avila-Reese, V., & Valenzuela, O. 2000, ApJ, 542, 622
Diemand, J., Moore, B., & Stadel, J. 2005, Nature, 433, 389
Hernandez, X., & Lee, W. H. 2008, MNRAS, 387, 1727
Johnson, M. C., & Kamionkowski, M. 2008, Phys. Rev. D, 78, 063010
Klypin, A., Kravtsov, A. V., Valenzuela, O., & Prada, F. 1999, ApJ, 522, 82
Green, A. M., Hofmann, S., & Schwarz, D. J. 2004, MNRAS, 353, L23
Green, A. M. 2010, arXiv:1004.2383
Murphy, T. W., et al. 2008, 16th International Workshop on Laser Ranging, ed. S. Schillak, `http://cddis.gsfc.nasa.gov/lw16`
Peñarrubia, J., Koposov, S. E., Walker, M. G., Gilmore, G., Wyn Evans, N., & Mackay, C. D. 2010, arXiv:1005.5388
Pitjeva, E. V. 2005, Sol. Sys. Res., 39, 176
Xu, D. D., Mao, S., Cooper, A. P., Wang, J., Gao, L., Frenk, C. S., & Springel, V. 2010, MNRAS, 408, 1721
Zhao, H., Taylor, J. E., Silk, J., & Hooper, D. 2005, arXiv:astro-ph/0502049