Lopsided Satellite Distributions around Isolated Host Galaxies

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Motivation: Testing Cold Dark Matter theory

CDM predicts that all large, bright galaxies live at the centers of enormous, *non-spherical* “halos” of *invisible* dark matter

Note: illustration is not to scale!
We expected to see elliptical *symmetry*

Large, bright galaxies tend to be surrounded by small “satellite” galaxies
What’s “new” about our sample?

• Previous studies of satellite galaxy locations had only 1 or 2 satellites per system

• Our host-satellite systems have at least 5 satellites per system

• Our sample allows systematic study of locations of satellites relative to each other within each system
Satellite galaxies of NGC2998 have a “lopsided” distribution.
A simple statistic to assess “lopsidedness”

Satellites 1 & 2 are on the same side of the host

Satellites 1 & 3 are on opposite sides
Preliminary Results (need to be independently confirmed)

• More pairs of satellites are on the same side of the host than on the opposite side ("lopsided" distribution)

• Effect is most pronounced for satellites of blue host galaxies (about 50% more pairs of satellites on same side of host than on opposite side)

• Effect is also present for satellites of red host galaxies (about 6% more pairs of satellites on same side of host than on opposite side)
Implications for Cold Dark Matter

• Unclear – we need to see if CDM simulations can reproduce our results

• “Lopsided” satellite distributions have been found between pairs of bright galaxies and CDM simulations seem to be able to reproduce that result

• Probably not a good idea to use locations of satellites as indicator of halo shape, especially for blue host galaxies
Contact Information and URL for Images and PPT Slides

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http://firedrake.bu.edu/aas236/press.html
Bonus Slides
Characteristics of Our Sample

• Source: NASA-Sloan Atlas

• Host galaxies have no similarly-bright neighboring galaxies within about 2.5 million light years (“isolated”)

• Host galaxies are at least as large and bright as our Milky Way galaxy

• Satellite galaxies are on average 25 times fainter than their host galaxy
References: Lopsided Satellite Distributions between PAIRS of Bright Galaxies


The Three-dimensional Structure of the M31 Satellite System; Strong Evidence for an Inhomogeneous Distribution of Satellites


We undertake an investigation into the spatial structure of the M31 satellite system utilizing the distance distributions presented in a previous publication. These distances make use of the unique combination of depth and spatial coverage of the Pan-Andromeda Archaeological Survey to provide a large, homogeneous sample consisting of 27 of M31’s satellites, as well as M31 itself. We find that the satellite distribution, when viewed as a whole, is no more planar than one would expect from a random distribution of equal size. A disk consisting of 15 of the satellites is however found to be highly significant, and strikingly thin, with an rms thickness of just 12.34^{+0.75}_{-0.43} kpc. This disk is oriented approximately edge-on with respect to the Milky Way and almost perpendicular to the Milky Way disk. It is also roughly orthogonal to the disk-like structure regularly reported for the Milky Way satellite system and in close alignment with M31’s Giant Stellar Stream. A similar analysis of the asymmetry of the M31 satellite distribution finds that it is also significantly larger than one would expect from a random distribution. In particular, it is remarkable that 20 of the 27 satellites most likely lie on the Milky Way side of the galaxy, with the asymmetry being most pronounced within the satellite subset forming the aforementioned disk. This lopsidedness is all the more intriguing in light of the apparent orthogonality observed between the satellite disk structures of the Milky Way and M31.
The Lopsided Distribution of Satellite Galaxies

Libeskind, Noam I.; Guo, Quan; Tempel, Elmo; Ibata, Rodrigo

The distribution of smaller satellite galaxies around large central galaxies has attracted attention because peculiar spatial and kinematic configurations have been detected in some systems. A particularly striking example of such behavior is seen in the satellite system of the Andromeda galaxy, where around 80% are on the near side of that galaxy, facing the Milky Way. Motivated by this departure from anisotropy, we examined the spatial distribution of satellites around pairs of galaxies in the Sloan Digital Sky Survey. By stacking tens of thousands of satellites around galaxy pairs, we found that satellites tend to bulge toward the other central galaxy, preferably occupying the space between the pair, rather than being spherically or axis-symmetrically distributed around each host. The bulging is a function of the opening angle examined and is fairly strong—there are up to ~10% more satellites in the space between the pair than expected from uniform. Consequently, it is a statistically very strong signal, being inconsistent with a uniform distribution at the 5σ level. The possibility that the observed signal is the result of the overlap of two halos with extended satellite distributions is ruled out by testing this hypothesis by performing the same tests on isolated galaxies (and their satellites) artificially placed at similar separations. These findings highlight the unrelaxed and interacting nature of galaxies in pairs.
The Lopsidedness of Satellite Galaxy Systems in \( \Lambda \)CDM Simulations

Pawlowski, Marcel S.; Ibata, Rodrigo A.; Bullock, James S.

The spatial distribution of satellite galaxies around pairs of galaxies in the Sloan Digital Sky Survey (SDSS) have been found to bulge significantly toward the respective partner. Highly anisotropic, planar distributions of satellite galaxies are in conflict with expectations derived from cosmological simulations. Does the lopsided distribution of satellite systems around host galaxy pairs constitute a similar challenge to the standard model of cosmology? We investigate whether such satellite distributions are present around stacked pairs of hosts extracted from the \( \Lambda \)CDM simulations Millennium-I, Millennium-II, Exploring the Local Volume in Simulations, and Illustris-1. By utilizing this set of simulations covering different volumes, resolutions, and physics, we implicitly test whether a lopsided signal exists for different ranges of satellite galaxy masses, and whether the inclusion of hydrodynamical effects produces significantly different results. All simulations display a lopsidedness similar to the observed situation. The signal is highly significant for simulations containing a sufficient number of hosts and resolved satellite galaxies (up to 5 \( \sigma \) for Millennium-II). We find a projected signal that is up to twice as strong as that reported for the SDSS systems for certain opening angles (~16% more satellites in the direction between the pair than expected for uniform distributions). Considering that the SDSS signal is a lower limit owing to likely background and foreground contamination, the \( \Lambda \)CDM simulations appear to be consistent with this particular empirical property of galaxy pairs.
The origin of lopsided satellite galaxy distribution in galaxy pairs

Gong, Chen Chris; Libeskind, Noam I.; Tempel, Elmo; Guo, Quan;
Gottlöber, Stefan; Yepes, Gustavo; Wang, Peng; Sorce, Jenny; Pawlowski, Marcel

It is well known that satellite galaxies are not isotropically distributed among their host galaxies as suggested by most interpretations of the Λ cold dark matter (ΛCDM) model. One type of anisotropy recently detected in the Sloan Digital Sky Survey (and seen when examining the distribution of satellites in the Local Group and in the Centaurus group) is a tendency to be so-called lopsided. Namely, in pairs of galaxies (like Andromeda and the Milky Way) the satellites are more likely to inhabit the region in between the pair, rather than on opposing sides. Although recent studies found a similar set-up when comparing pairs of galaxies in ΛCDM simulations indicating that such a set-up is not inconsistent with ΛCDM, the origin has yet to be explained. Here we examine the origin of such lopsided set-ups by first identifying such distributions in pairs of galaxies in numerical cosmological simulations, and then tracking back the orbital trajectories of satellites (which at z = 0 display the effect). We report two main results: first, the lopsided distribution was stronger in the past and weakens towards z = 0. Secondly, the weakening of the signal is due to the interaction of satellite galaxies with the pair. Finally, we show that the z = 0 signal is driven primarily by satellites that are on first approach, who have yet to experience a ‘flyby’. This suggests that the signal seen in the observations is also dominated by dynamically young accretion events.