Probing Halo Mass Distributions Through Weak Lensing

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Abstract

Measuring the mass distributions within dark matter halos, and in particular the masses of subhalos, can provide key insights into the timing and extent of tidal stripping of the subhalos. Using halo models to simulate weak lensing signals around groups and satellites with various mass distributions, we show that weak lensing provides a sufficiently powerful tool to differentiate between groups whose satellite galaxies have undergone tidal stripping and those which haven't. In order to have the statistical power to overcome the noise inherent in lensing, we project a need for ~60 deg.[2] of data with spectroscopic redshifts for foreground galaxies and shape measurements for background galaxies. We plan to apply these results to data from the CFHTLS-Wide for an empirical comparison.

Background

It has been found in past work[1] that star formation drops off as galaxies join groups, but the mechanism for this is not yet known. One possible cause for this is tidal stripping of gas from galaxies. Weak gravitational lensing provides a potential method to measure the extent to which stripping has occurred, and the wealth of shape data provided by the CFHTLS-Wide (up to 170 deg.[2]) may be enough to overcome the noise inherent in weak lensing and measure the extent of stripping.

However, it is first necessary to predict what lensing signal will be seen around both stripped and unstripped galaxies. Our plan is to use simulated galaxy catalogues to test methods for determining the extent of galactic stripping and to determine how much data will be required to measure it.

Methodology

In order to predict the lensing signals we might expect to see, we apply a ray-tracing algorithm to galaxy catalogues extracted from the Millennium simulation to develop a shape catalogue for background galaxies. To minimize noise in our measurements, we start with each background galaxy having a perfectly circular shape. Rather than using the locations of dark matter particles as our foreground mass distribution, we use a hierarchical NFW halo model for the mass.

Using this model allows us to adjust how much mass is contained in group halos versus satellite halos. For our purposes, we use the following four mass distributions, where infall masses are estimated from satellites' stellar masses:[2]

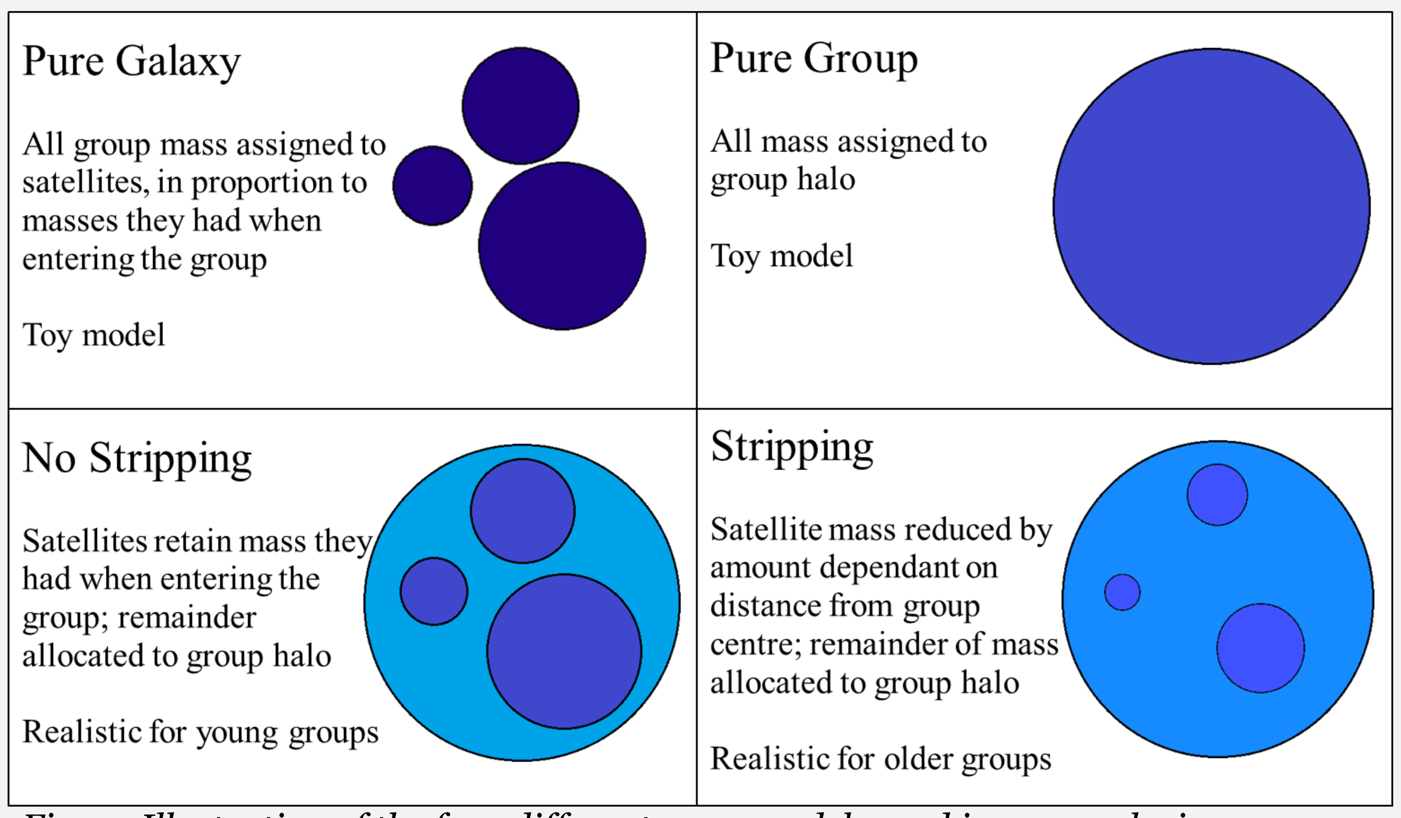

Fig. 1—Illustration of the four different mass models used in our analysis.

We also include in our analyses the results of a ray-tracing algorithm perform by Jan Hartlap *et al.*, which uses the positions of dark matter particles within the simulation as its foreground mass distribution. This catalogue, deemed “Particle Ray-Tracing” or “PRT,” provides a useful check of the accuracy of our models.

Once our shape catalogues have been generated, we stack the lensing signals around selections of foreground galaxies to obtain an average signal for the selection. Our selections include sets of group centres, sets of all satellites, and sets of satellites in groups of different masses.

In order to isolate the lensing signals of satellite galaxies from the signal contributed by their host group, we also construct a modified lensing signal around selections of satellites. To accomplish this, we calculate the lensing signal around a set of points that are positioned opposite the central galaxy from each satellite in the selection, and we subtract this signal from the signal around the satellites themselves. These points are expected to see the same contribution to their lensing signal from the groups' halos as the satellites, but very little from the satellites themselves, and so the modified signal should represent only the contributions from the satellites.

Results

The greatest difference between models was found in the lensing signal around satellites (shown in Fig. 2). Our models match reasonably with the results of the particle ray-tracing simulation, although the PRT lensing signal seems to show a larger contribution from the group's halo. Even within ~200 kpc of the satellite, this contribution isn't negligible, and so it must be accounted for. As this would make comparing satellites in groups of different masses impossible, we decided to instead attempt to subtract out the group's contribution to the lensing signal.

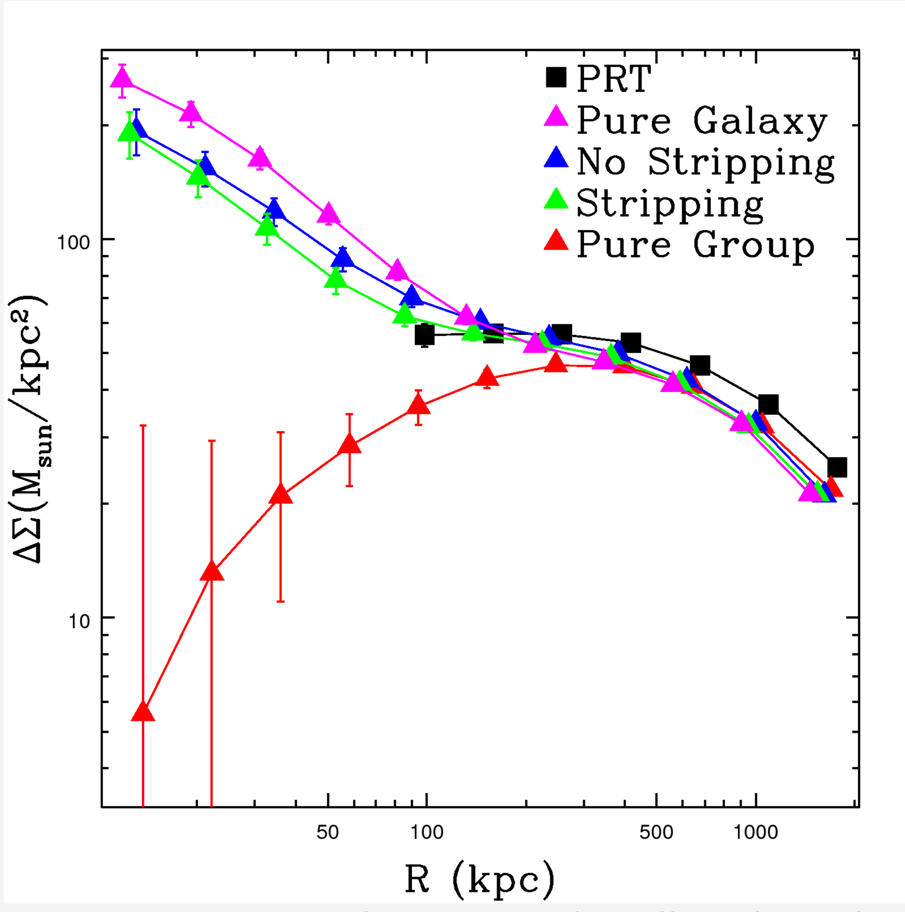

Fig. 2—Lensing signal (ΔΣ) around satellites, binned by projected distance between satellites and sources (R), showing our five mass models and a comparison with particle ray-tracing results. PRT shears are not shown below the resolution limit of the simulation. Error bars show projected errors from shape noise for 64 deg.[2] of data.

This modified signal (shown in Fig. 3 shows better agreement between our models and the PRT data. Notably, it also shows that the lensing signal does not vary with group mass. This implies that the remaining difference between our lensing signal and that of the PRT data is due to our method of assigning satellite mass, which may not be optimal. However, this does show that this method can be used to compare satellites in groups of different masses, which will ultimately allow us to determine at what group mass tidal stripping begins to play a role.

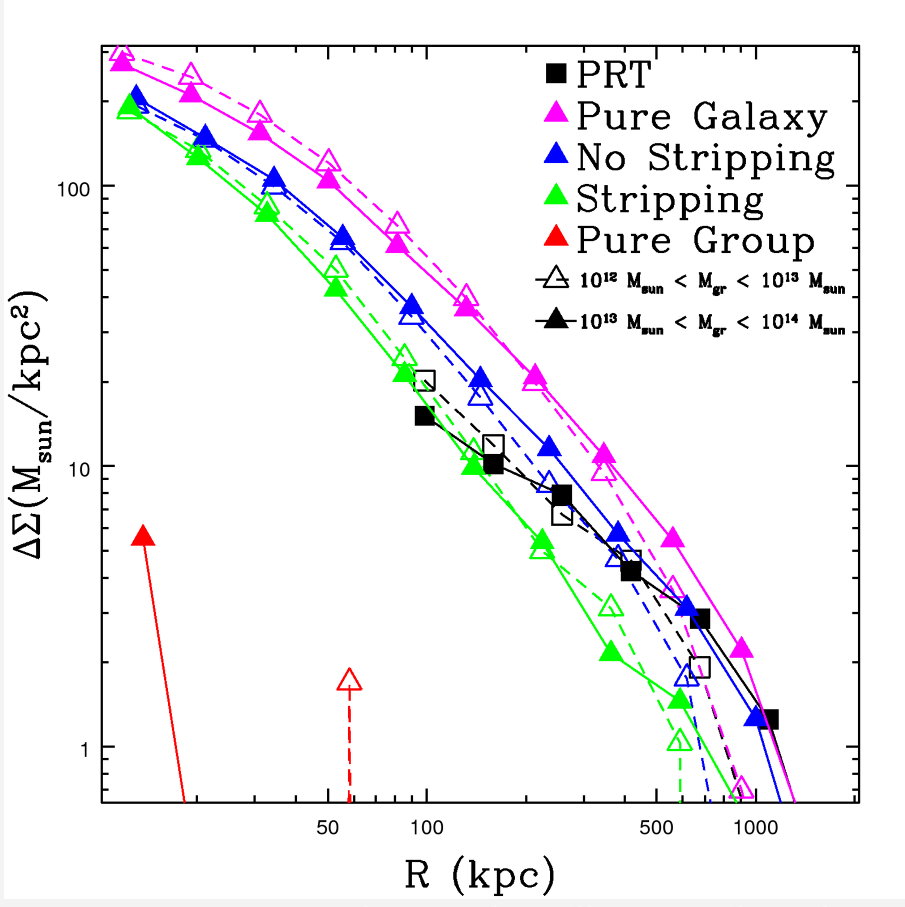

Fig. 3—Lensing signal around satellites, as above but corrected to subtract out signal from group centres, and comparing satellites from groups of different masses.

The greatest difference between the stripped and unstripped models is in sources lying in radial annuli of 50-200 kpc around the satellites, so this would be the range to focus on in future observations. With 64 deg.[2] of simulated data, the two models are separated by approximately twice the standard error, so we will need ~60 deg.[2] of data with spectroscopic redshifts and shape data for a real-world measurement.

Outlook

We've shown that it is possible to use weak lensing to determine whether or not a selection of galaxies have been tidally stripped, which will help determine if tidal stripping is causing the observed drop-off in star formation when galaxies join groups. This will require ~60 deg.[2] of data that has both spectroscopic redshifts for foreground galaxies and shape measurements for background galaxies, which will soon be available. Forthcoming data from the GAMA and VIPERS surveys will provide a combined ~60 deg.[2] of spectroscopic data. These surveys overlap with the fields from the CFHTLS-Wide survey, which have shape data, so this will allow us an imminent test of our methodology.

[1]*Parker et al., 2005, among others*

[2]*Using Eq. 3 from Guo et al., 2010*