BACKGROUND:

(Correlating dark matter haloes with large-scale structure of the cosmic web, how it points towards the hierarchical structure formation)

(STRUCTURE FORMATION THEORY?)

The standard theory for the origin of angular momentum in the large-scale structure of the universe is the framework of hierarchical structure formation, which occurs due to the assumption that gravitational instability draws structures together. That is, that most angular momentum is gained gradually by dark matter haloes (or the beginnings of them at least, protohaloes) in the linear regime of the growth of density fluctuations that occur due to tidal torques from neighbouring fluctuations.

So there is this idea that angular momentum in structures like dark matter haloes exists due to their local environment. That is, what was originally a background of density fluctuations, but now forms an intricate web of dark matter structures on a large-scale. The importance of dark matter haloes is that these are where baryonic material clump together to an extent where it undergoes a virial shock and forms galaxies.

(WHY STUDY IT?)

A reason for investigating one a large scale these processes is the ‘spin crisis’ seen in simulations today, where luminous galaxies produced in large scale cosmological simulations (which are essentially the only means we have of investigating the structure and evolution of the universe) are observed to be significantly smaller and with much less angular momentum than observed in disc galaxies. There is also motivation coming from the need to understand angular momentum build up processes in order to develop semi-analytic models capable of galaxy formation. Finally, in a more observational sense, there is a need to understand these processes in order to work around them when doing weak gravitational lensing studies.

In particular relevance to this project, the increased observational ability of radio astronomy also means that a new area of the dark matter halo has been opened up to investigation – the stellar halo.

AIM:

(CORRELATION WITH COSMIC WEB)

A number of previous studies have found that dark matter haloes (within which baryonic galaxies form) have structural properties that correlate with their local environment, that is, the part of the cosmic web that they reside in. This local environment can be thought of as different densities, or more specifically, as voids, walls and filaments along which haloes can be aligned or misaligned. The fact that these halo properties correlate with the local environment suggests that the baryonic galaxies that form within will likely do so as well, albeit to a lesser degree. In particular, the stellar halos made up of these galaxies could possibly show a correlation to local environment.

(AIM)

In this project, we wish to measure the properties of stellar haloes in the Horizon-AGN hydrodynamical simulation, as well as information about the cosmic web in which they reside (their local environment). These structural properties – orientation, mass and angular momentum profiles – will then be measured against the orientation and properties of the cosmic web to see if a correlation exists.

METHOD:

(I.e. computing the inertia and shear tensor, using linear tidal torque theory to relate this to the angular momentum, using the inertia tensor to get the shape)

The interesting thing about this project is there is no right way to go about it – the aim is to derive as many different possible structural quantities from the stellar halo and essentially determine if there is any correlation between these and their local environment. One possible way of doing so (which has been used extensively in the literature in determining structural properties of dark matter halos and their central galaxies) is to compute the moment of inertia tensor (which represents information about the intrinsic alignment or spin of a galaxy) and compare this with the tidal shear tensor (which represents information about the filament direction, i.e. the surrounding large-scale structure of the cosmic web and how it deforms the dark matter halo). Recent papers have also used projected quantities in the line of sight in an effort to make simulation results more easily applicable to future weak gravitational lensing studies.

The data for the simulation is stored on Magnus, and the supercomputer will have to be used to compute the structural properties over such a large data set. Programs that will be used include DisPerSE, which stands for Discrete Persistent Structures Extractor, which will be used to compute the cosmic web from the simulation data.

To do this,

CONCLUSION:

In conclusion, this project offers an insight into an as of yet unexplored subset of the wide and interesting field that is the correlation between dark matter haloes and their substructures with the large-scale cosmic web they are embedded in. The project is all the more interesting since it holds a real relevance given the increasing ability of radio astronomy to extract observational data from stellar haloes, as well as the need for further work to be done in this area to clear the way for future studies in weak gravitational lensing.