Exploratory observations with stellar streams

Dark matter constitutes approximately 26% of the current energy density of the universe and plays a central role in large-scale structure formation. Yet, aside from its gravitational effects, very little is known about what constitutes dark matter and the space of possibilities for dark matter candidates remains vast. Various high-energy physics experiments have been constructed with the explicit aim of detecting specific dark matter candidates. They have been complemented with ever more detailed cosmological and astrophysical observations to constrain the dark matter space of possibilities.

This paper investigates the epistemological underpinnings of one recent set of observations: the use of stellar streams to map out the substructure of the Milky Way halo and thereby further constrain possible dark matter candidates (see for example Bonaca et al 2019). Stellar streams are clusters of stars orbiting a galaxy that have been torn apart and stretched out due to tidal effects. They move through the presumed dark matter halo of that galaxy, which means that they could encounter substructure in that halo. Any encounters with substructure would affect the density profile of the stream. Observations of density profiles of stellar stream in the Milky Way halo density profiles thus helps to explore the possible substructure present in the Milky Way halo, which, in turn could lead to further constraints on the space of possibilities for dark matter candidates on the one hand, and on the range of possible solutions to some of the small-scale challenges in cosmology on the other hand.

In this paper, I investigate the epistemic status of such stellar stream observations. I argue that stellar stream observations fulfill a dual role. They constitute exploratory observations insofar as they are used to map out the substructure of the Milky Way halo, but they are hypothesis-driven insofar as they are used to investigate how the structure of stellar streams is affected by interaction with that substructure.

In my argument, I draw on the existing literature on exploratory experiments and extend it to the current case. Exploratory experiments are commonly defined in contrast with confirmatory or hypothesis-driven experiments: they are not aimed at testing any specific local theory about the target (see e.g. Franklin 2005). Although exploratory experiments are not aimed at testing any local theory about the target, that does not mean they do not rely on such theoretical background. There is broad recognition that exploratory experiments require background theory as guidance (Franklin 2005, Karaca 2013). Building on Colaço (2018), I show that the stellar streams case reveals that sometimes observations and experiments can take on a dual role as both exploratory and hypothesis-driven, but with regards to different targets: dark matter haloes, and stellar streams, respectively. I close with an analysis of how this dual role plays out in practice.

References

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