How dark matter came to matter

A history of missing mass, 1930-1974

de Swart, J.G.

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ABSTRACT

According to the prevailing cosmological model, 85% of the universe's mass consists of "dark matter" – an elusive substance that is distributed throughout the universe and is undetectable by optical means. As of yet, the nature of the dark matter has been unknown for over 40 years. This thesis is about the *history* of the dark matter problem; it probes the historical conditions under which dark matter became a fundamental part of the canon of cosmology.

The dissertation traces the history of two phenomena that are currently regarded to be evidence for dark matter's existence: the rapid rotation of galaxies, and the dynamics of galaxies in clusters. Unlike many popular historical accounts have argued, it is shown that these phenomena, as they were observed during the 1960s, were *not* directly interpreted as evidence for dark matter. Observations of galaxies and clusters of galaxies were only shaped into evidence for dark matter within a new hybrid scientific environment that arose in the early 1970s, that of *physical cosmology*. Driven by new observations and postwar technological developments, many young scholars engaged in doing a physics of the universe. Within this cosmological practice, concerns about "missing mass" in the universe arose. In 1974, two groups of astronomers and physicists combined the existing observations from galactic and extra-galactic astronomy to evidence that this missing mass indeed existed: galaxies were ten times more massive than was previously thought. In this context, dark matter came to matter.

PUBLICATIONS

Some of the material in this thesis has previously appeared in the following publications:

J. de Swart, G. Bertone, and J. van Dongen, "How dark matter came to matter," *Nature Astronomy* 1, no. 3 (2017): 0059.

J. de Swart, "Deciphering dark matter: the remarkable life of Fritz Zwicky," *Nature* 573, no. 7772 (2019).

J. de Swart, "Closing in on the Cosmos: Cosmology's Rebirth and the Rise of the Dark Matter Problem," in *The Renaissance of General Relativity in Context. Einstein Studies, vol 16*, ed. Alexander Blum, Roberto Lalli, and Jürgen Renn (Cham: Birkhäuser, 2020).

COLOPHON

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