Thesis subject

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Subject's title: Galaxy Clusters in the James Webb Space Telescope Era:
Dark Matter Properties & Gravitational Telescope

Subject description:

This thesis proposes to pursue a precise mass modelling for a sample of galaxy clusters observed with the James Webb Space Telescope (JWST), providing clues on the nature and properties of the elusive dark matter (DM) which is thought to constitute most of the mass of galaxy clusters. These mass models will help to use these clusters as gravitational telescopes, pushing the frontiers of current facilities to access the high redshift Universe.

The cosmic web was revealed observationally in the 1980s by the first large spectroscopic redshift surveys in agreement with theoretical and numerical predictions from hierarchical structure-formation scenarios (*e.g. White et al.* 1987). Within this paradigm, massive galaxy clusters form at the vertices of the cosmic web by continuous as well as sporadic and smooth accretion of matter along filamentary structures connecting them.
Studying these nodes of the cosmic web provides insights into structure formation and evolution scenarios (*e.g. Limousin et al.,* 2016). The amount of mass (mainly DM) they contain and how this mass is distributed is routinely used to constrain the nature and properties of DM (*e.g. Sand et al.,* 2004; *Smith et al.,* 2009).
A galaxy cluster, given its mass, locally deforms space-time, so that the light coming from distant background galaxies and passing by a cluster is deflected. In the core of massive galaxy clusters we observe multiple images of single background sources, this is called the strong lensing (SL) regime. In the outskirts, we observe slight distortions in the shapes of background galaxies, a regime called weak lensing (WL).
These observations provide valuable constraints on the mass distribution of galaxy clusters. In the last decades, gravitational lensing has become an incontournable tool to map the mass distribution of galaxy clusters, from the core to the outskirts (*e.g. Limousin et al.,* 2007).

Complementary methods include X-ray studies and measure of the velocities of galaxy cluster members. In the recent years, it has become clear that any mass modelling should take into account different probes of the gravitational potential (*e.g. Limousin et al.,* 2013; *Bonamigo et al.* 2018; *Bergamini et al.* 2019).
We propose to use JWST data to pursue precise mass modelling of a sample of galaxy clusters for which X-ray (Chandra/XMM) and spectroscopic data (MUSE) are available.
JWST opens a new area in SL studies, providing a wealth of observational constraints (*e.g. Mahler et al.*, 2023).
The mass associated with cluster members will be constrained by spectroscopic measurements. X-ray data will allow for a description of the intra cluster medium (ICM). For the first time, JWST reveals the intra cluster light (ICL), an ingredient which is recognized worth considering in cluster mass modelling (*Montes & Trujillo,* 2022). All these ingredients will be considered jointly in the modelling, using new functionalities recently implemented (*Beauchesnes et al.,* submitted, for the inclusion of X-ray constraints) within the Lenstool software developed at LAM (*Jullo et al.,* 2007). During the course of this thesis, we will also continue to develop new functionalities in Lenstool. This software being widely by our community, these implementations will be useful world wide.

The proposed project aims to use the most recent data and analysis tools in order to pave the road towards the next generation of galaxy cluster mass modelling.

Such precise mass modelling will provide insights into cluster physics. Taking benefit of the disentanglement of all cluster components (DM, Galaxies, ICM and ICL), we will probe the profile of the DM in the inner core, providing constraints on the nature of DM, in particular its possible self interaction (*Limousin et al.,* 2022). Comparing the distributions of DM, ICM and ICL will shed light on the dynamical state of these clusters, and we will also address the hydrostatic mass biases.
Besides, the mass models produced will be used by the community in order to use these clusters as gravitational telescopes, using the amplification naturally provided by these clusters. Special care will be given to provide reliable errors on magnification estimates.

Since last summer, several galaxy clusters (half a dozen) have already been observed by JWST. Some observations are already public, and all of them will become available next summer. Our team is currently writing a JWST proposal in order to observe more lensing clusters which are already known and do have complementary data sets. Different teams are proposing such observations, ensuring that the science goals of this thesis will not depend on any telescope time allocation.

Bibliography:

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