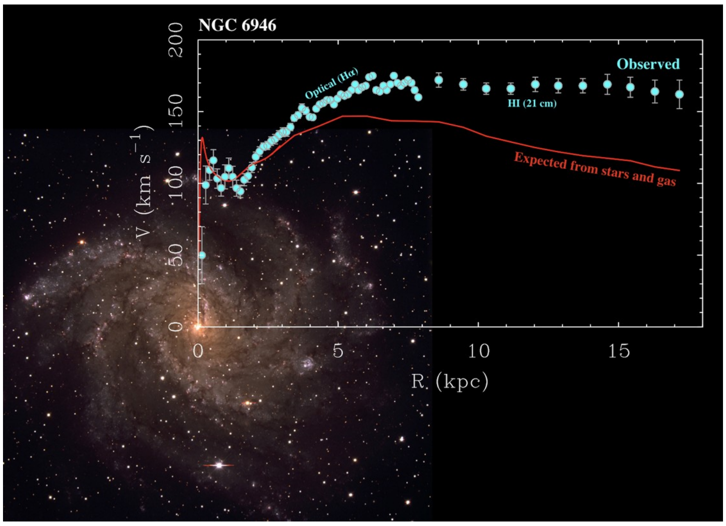
PhD Thesis Project Proposal
INAF – Osservatorio Astrofisico di Arcetri

Title – Dark Matter in Disk Galaxies across Cosmic Time

Advisor: Federico Lelli, federico.lelli@inaf.it – INAF-Osservatorio Astrofisico di Arcetri
Period: November 2023 - November 2026

Description –
The study of rotation curves in nearby galaxies (at redshift z=0) has been crucial to establish the dark matter (DM) problem and continues to play a key role in testing both the standard cosmological model LCDM (e.g., Katz et al. 2017) and alternative gravitational theories (e.g., Lelli et al. 2017a, 2017b). To date, extended rotation curves, which reach the regime where DM dominates over baryonic matter, have been derived for "just" a few hundreds galaxies using radio observations of atomic hydrogen (HI) at 21 cm. In the next years, however, large HI surveys with pathfinders of the Square Kilometre Array (SKA) will allow us to measure rotation curves for thousands of galaxies at z=0, so it will be possible to perform statistical studies of the DM content that were unfeasible until a few years ago.

In addition, over the past few years, it has become possible to trace rotation curves in primordial galaxies at high redshift (z>1) but the observational situation remains debated (Di Teodoro et al. 2016; Genzel et al. 2017). Most of the existing studies trace rotation curves using the H-alpha emission line, which do not reach the outermost galaxy regions where DM heavily dominates over baryons (see figure). The [CII] line of ionized Carbon, tracing a combination of atomic, molecular, and ionzied gas, is a promising tracer to measure extended rotation curves at z>4 using deep interferometric observations with the ALMA telescope (e.g., Lelli et al. 2021, Science).



Near-infrared image of the nearby spiral galaxy NGC 6946. The inset shows the observed rotation curve (blue points) obtained by combining ionized gas data (H-alpha) from optical observations in the inner parts with atomic gas data (HI) from radio observations in the outer regions. The red line shows the expected rotation velocities inferred from the observed distribution of baryons (gas and stars). The discrepancy at large radii is the classic evidence for DM.

Objectives –
The student will perform a comparative and evolutionary study of gas dynamics and DM across cosmic time, starting from nearby galaxies (z=0) up to high-z galaxies (z=4-5).

Regarding galaxies at z=0, the student will analyze existing HI data compiled by the advisor as well as new HI data that are being obtained with the Australian SKA Pathfinder (ASKAP) by the WALLABY and DINGO collaborations, in which the advisor is involved.

Regarding galaxies at high z, the student will analyze existing [CII] data from ALMA together with upcoming JWST images obtained by the advisor as part of the international TRICEPS collaboration.

The student will measure rotation curves and build mass models by calculating the gravitational potential expected from the distribution of visibile mass (gas and stars). This will allow him/her to quantify the distribution of DM and test the predictions of the standard cosmological model LCDM as well as alternative gravitational theories.

The student will be free to decide the appropriate balance in studying galaxies at z=0 and galaxies at high z depending on his/her own interests.

References – Katz H., Lelli F. et al. 2017, MNRAS, 466, 1648, arXiv:1605.05971
Lelli F. et al. 2017a, ApJ, 836, 152, arXiv:1610.08981
Lelli F. et al. 2017b, MNRAS, 468, L68, arXiv:1702.04355
Genzel R. et al. 2017, Nature, 543, 397, arXiv:1703.04310
Di Teodoro E. et al. 2018, A&A, 594, A77, arXiv:1602.04942
Lelli F. et al. 2021, Science, 371, 713, arXiv:2102.05957