Understanding the interaction of bars and spirals

SUMMARY.

More than half of all spiral galaxies, including our own Milky Way, host bars. This METEOR will seek to understand one of the least understood aspects of bars, which is their interaction with spirals. This project will use numerical simulations to explore how bars and spirals interact, with a goal of providing diagnostics of their co-evolution that can be used in future studies. The results of the project will have applications to several current large surveys, including from ESA's *Euclid* satellite, and ground-based surveys such as REDWAY.

OBJECTIVES

- Students will learn about the dynamics of bars and of spirals. They will explore how their interactions can be observed in the Milky Way, setting the stage for applications to REDWAY data.
- Students will develop skills in using simulations to answer detailed questions about the evolution of galaxies. They will also learn how to project simulations into the space of Milky Way observables, to provide predictions for future observations.

INSTITUTE

- University of Lancashire
- https://www.lancashire.ac.uk/
- Preston, United Kingdom

THEORY

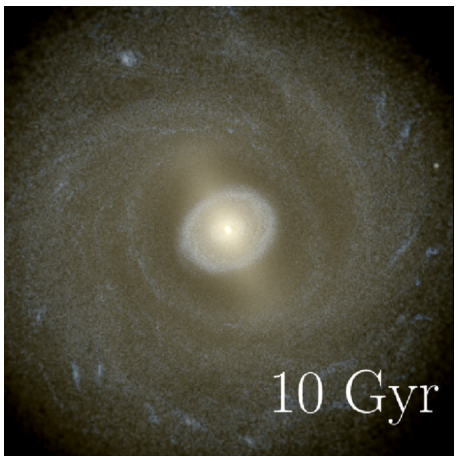
by Victor P. Debattista

Bars in galaxies are very common in the nearby universe and have been found to already be present in galaxies as early as redshift $z \sim 4$. Bars drive evolution within the galaxy by transferring angular momentum from the bar to stars further out, and to the dark matter halo. The effect of the bar on the evolution of galaxies is amplified by the presence of spiral arms, which comprise density waves travelling through the stellar disc. At the ends of bars, the spirals often appear to be connected to the bar, giving the impression that the bar is driving the spirals. But in general spirals and bars rotate with different angular frequencies. Instead, what seems to happen is that spirals repeatedly detach and re-attach to the ends of the bar as the two rotate relative to each other.

While this behaviour has been known for some time, what this means for the velocities of stars, star formation and stellar chemistry is not known. This project will use high time-resolution simulations to follow the motions of stars and gas, and the properties of star formation at the interface of bars and spirals to understand their interaction better. Results of this work can form the basis of followup work in either the Milky Way or external galaxies to confirm that this complex behaviour is taking place.

APPLICATIONS

by Victor P. Debattista



Students will first follow the evolution of a bar and spirals in a simulation, such as the one above, tracing their attachments and detachments. The students will then measure the kinematics of gas and stars, the star formation rate, and the chemistry of new stars. These properties will then be stacked across time as a function of the relative state of the bar and spirals. In the last step the observables will be viewed as in the Milky Way. This will permit future data, from the REDWAY survey using the newly built MOONS instrument for the VLT, to unravel the interplay between bars and spirals.

MAIN PROGRESSION STEPS

- `Weeks 1-9`: Follow course in Galaxies, if desired
- `Week 1`: Understanding Python code for simulation analysis
- `Week 2`: Preliminary analysis of simulations
- `Weeks 3-9`: Project work

EVALUATION

- `Theory grade [30%]`
  - Oral presenation of results (80%): Weekly
  - Presentation of an article (20%): critical spirit
- `Practice grade [30%]`
  - Project (80%): initiative, progress, and applications
  - Code development (20%): clear and reusable code
- `Defense grade [40%]`
  - Oral and slides quality
  - Context
  - Project / Personal work
  - Answers to questions

BIBLIOGRAPHY & RESOURCES

- Sellwood & Sparke 1988
- Ardèvol et al. 2026

CONTACT

ℹ Victor P. Debattista
☎ +44 1772 893568
✉ vpdebattista@gmail.com