STAR FORMING NUCLEAR RINGS AND BARS: THEIR ROLE IN FEEDING SUPER-MASSIVE BLACK HOLES

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Supplying gas to the central pc of galaxies is a key ingredient for understanding the complex nuclear activity made of gas outflows, ionized jets, high-energy particles, HII regions, circumnuclear rings and spirals etc. In this respect, stellar bars are particularly important in disk-like galaxies where they may channel gas towards the galaxy nucleus to fuel both star formation and AGN activity. In the presence of an Inner Lindblad Resonance, the gas may pile up to form a ring in which star formation is subsequently triggered with the onset of gravitational instabilities, turbulence and cloud collapse. The importance of the most compact form of bar-driven nuclear rings, in the wider context of galaxy evolution scenarios, is now well-recognized. The dynamical processes involved drive secular evolution of their host galaxies. They transform gas flowing towards the central regions of a galaxy into stars, and hence not only mediate the gas flow to the nucleus, but also aid in the formation of the bulge and occasionally a *nuclear bar*. Nuclear rings and bars are rather common in spiral galaxies: they are observed in about 20% of nearby face-on spiral galaxies, and are thus as common as AGN activity.

The physical mechanisms which take over from the nuclear bar and rings to remove angular momentum have been suggested by theoretical studies [1] and only partially confirmed by numerical studies [e.g. 2]. Indeed, inside the innermost circumnuclear ring, the interstellar medium is highly inhomogeneous and certainly turbulent. Moreover, the growth of the central super-massive black hole (SMBH) comes with a variety of feedback mechanisms (outflows, winds, jets, etc.) which may partially block gas fueling. The interplay of fueling, star formation and feedback mechanisms leads to the so-called AGN variability.

While the general theoretical picture on the formation of stellar and gaseous nuclear structures is fairly clear, the *detailed* mechanism of how star formation occurs and proceeds within and around the ring is not well-established. Moreover, nuclear bars seem to be eventually associated to nuclear rings but the formation of nuclear bars has remained puzzling in spite of the efforts made by several groups to get realistic modelling of these complex systems. The difficulty to make up a standard scenario for the evolution of the central kpc, including AGN variability, is certainly not due to the lack of models for understanding how the stellar material can be assembled to form the inner bar but is rather due to the coexistence of several credible physical mechanisms.

Most of these mechanisms have been studied through numerical simulations (N−body and/or hydrodynamical simulations). Numerical simulations need to be improved and analyzed in great details [2]. The formation of nuclear rings and bars depends heavily on the physical conditions of the gaseous component. Local star formation and gas dynamics are both intricately responsible for shaping the central regions in a way that has not been fully understood yet [3]. Many surveys of the central kpc in nearby galaxies are in progress ([4]

and reference therein, EWASS Special Session in April 2018), making use of state-of-the-art instruments (e.g. ALMA, VLT/MUSE, VLT/SINFONI, GEMINI/GMOS). Thanks to numerical experiments it is however possible to identify the physical mechanisms responsible for the ignition of the local star formation inside the ring and to recover the history of both the ***stellar structures (ring/bar) formation*** and the ***stellar formation inside these structures***.

The student has thus to make an in-depth analysis of numerical simulations that span a range in the space of initial conditions, with a particular focus on the central kpc. New developments should implement new diagnostic tools inspired by observational measurements, improve the spatial and temporal resolution as well as include realistic AGN feedback recipes. Once the physical mechanisms are better understood, she/he will imagine observational tests that could lead to proposal on adequate facilities (such as ALMA, VLT, etc.). Comparisons with observations [e.g. 4, 5] will provide additional insight in the physical processes at play in the central regions.

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