Highlights of Astronomy, Volume 16
XXVIIIth IAU General Assembly, August 2012
T. Montmerle, ed.

doi:10.1017/S1743921314005857

The Lifetimes of Spirals and Bars

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Simulations of isolated galaxy disks that are stable against bar formation readily manifest multiple, transient spiral patterns. It therefore seems likely that some spirals in real galaxies are similarly self-excited, although others are clearly driven by tidal interactions or by bars. The rapidly changing appearance of simulated spirals does not, however imply that the patterns last only a fraction of an orbit. Power spectrum analysis reveals a few underlying, longer-lived spiral waves that turn at different rates, which when super-posed give the appearance of swing-amplified transients. These longer-lived waves are genuine unstable spiral modes; each grows vigorously, saturates and decays over a total of several orbit periods. As each mode decays, the wave action created as it grew drains away to the Lindblad resonances, where it scatters stars. The resulting changes to the disk create the conditions for a new instability, giving rise to a recurring cycle of unstable modes.

Transient spiral modes are one of the most important agents of secular evolution in disk galaxies. They redistribute angular momentum, cause the random motions of stars to increase over time, and changes at corotation cause extensive radial mixing of both the stars and the gas, as discussed elsewhere at this conference. I also show here that they are able to smooth small-scale irregularities in the radial mass profile of the disk.

We still do not understand why some galaxies have strong bars, while others do not. A mild deficiency of bars in galaxies with massive bulges (Barazza *et al.* 2009) seems consistent with Toomre's stabilizing mechanism, but some barred galaxies should have been stable while other supposedly unstable cases, such as M33, lack strong bars! Skibba *et al.* (2012) have resurrected the idea that mild interactions may trigger some bars.

We have long known that steady, long-lived bars are built from stars pursuing elongated orbits that all turn at the bar pattern speed, and the majority remain within the bar. A significant minority of stars, however, cross and re-cross corotation but are unable to escape to the outer disk unless the bar weakens, or changes in some other way. Some stars in thick disk of the Milky Way have migrated from the inner Galaxy, but the outward flux of stars from the very innermost regions must have been curtailed when the bar formed. Thus identifying the oldest stars in the thick disk having chemical abundances characteristic of the inner Milky Way may allow us to estimate when the bar formed.

Bars in purely stellar particle simulations are very robust. Gas dynamics has been invoked to suggest that they could form and decay several times in the life of a galaxy, but recent cosmological simulations (Kraljic *et al.* 2012) seem to show that this does not happen, except possibly in the tumultuous early stages. Kormendy makes a strong case that bars dissolve to make pseudo-bulges, but the mechanism by which this could happen is unclear as yet.

References

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