Orbital Migration in Nuclear Stellar Disk Driven by Expanding Cloud Ring

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We investigate how stars in the nuclear stellar disk (NSD) migrate under an expanding molecular cloud ring and how this process shapes the stellar age gradient. We build a model with an axisymmetric background potential (Milky Way disk + dark matter halo + NSD) and a time-dependent cloud ring assembled from multiple Plummer spheres, each with its own lifetime. We integrate the orbits of NSD stars born in the ring region as the ring expands. For each star we compute the angular momentum L_z and radial action J_R, and identify churning (changes in L_z at fixed J_R) and blurring (changes in J_R) as a function of birth radius and time.

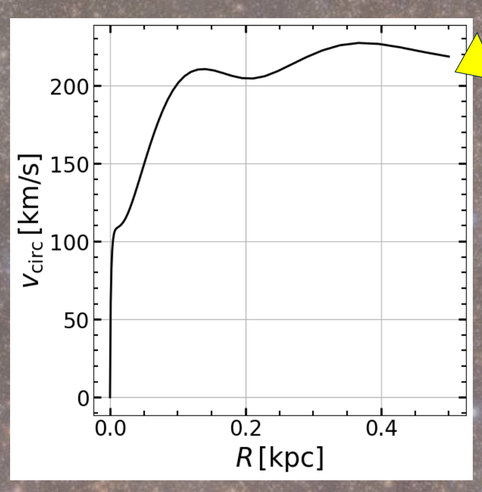
We find that churning predominantly originates within the ring region and persists throughout the simulation, occurring when stars are in corotation resonance with the dominant clouds. Blurring instead concentrates at the outer edge of the ring and becomes more frequent at later epochs, affecting stars off corotation. Despite this ongoing radial migration, the stellar age gradient is preserved under the influence of the expanding ring.

Numerical Model

NSD + MW potential + Expanding Cloud Ring

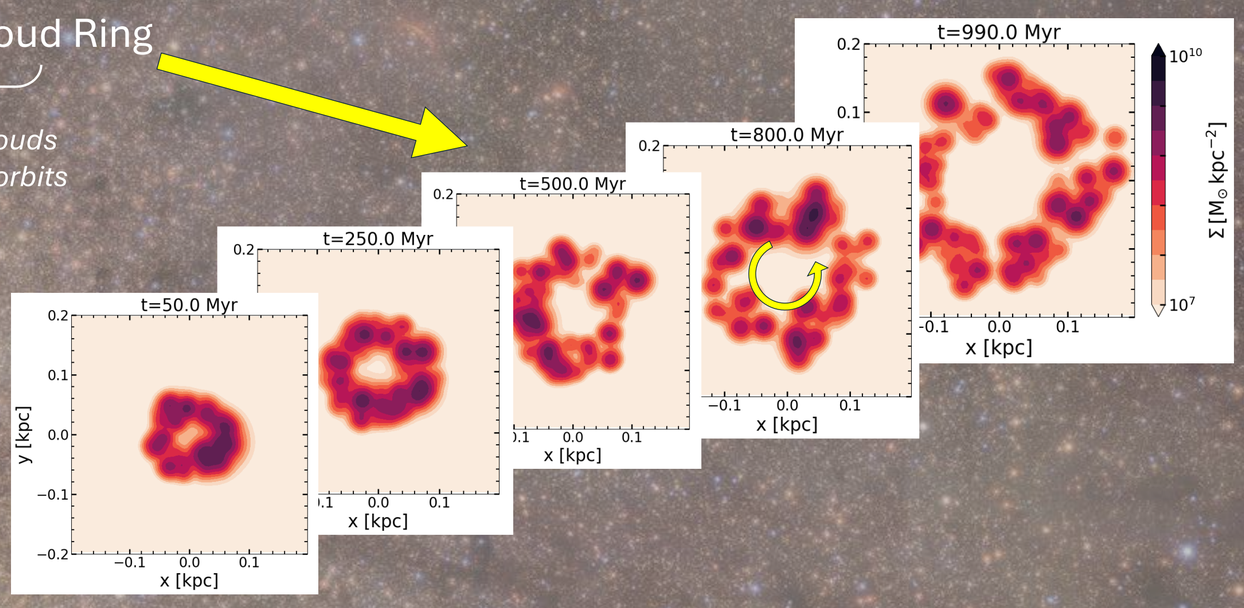
axisymmetric

transient clouds on circular orbits



+ Test Particles

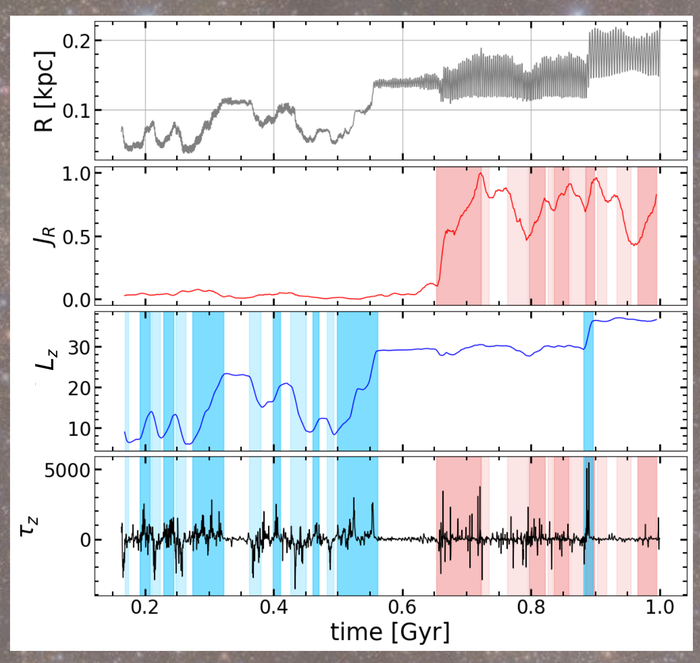
stars born within the ring region as it expands to resemble the "inside-out" growth scenario



Blurring and Churning

Detecting Blurring and Churning from a Single Star

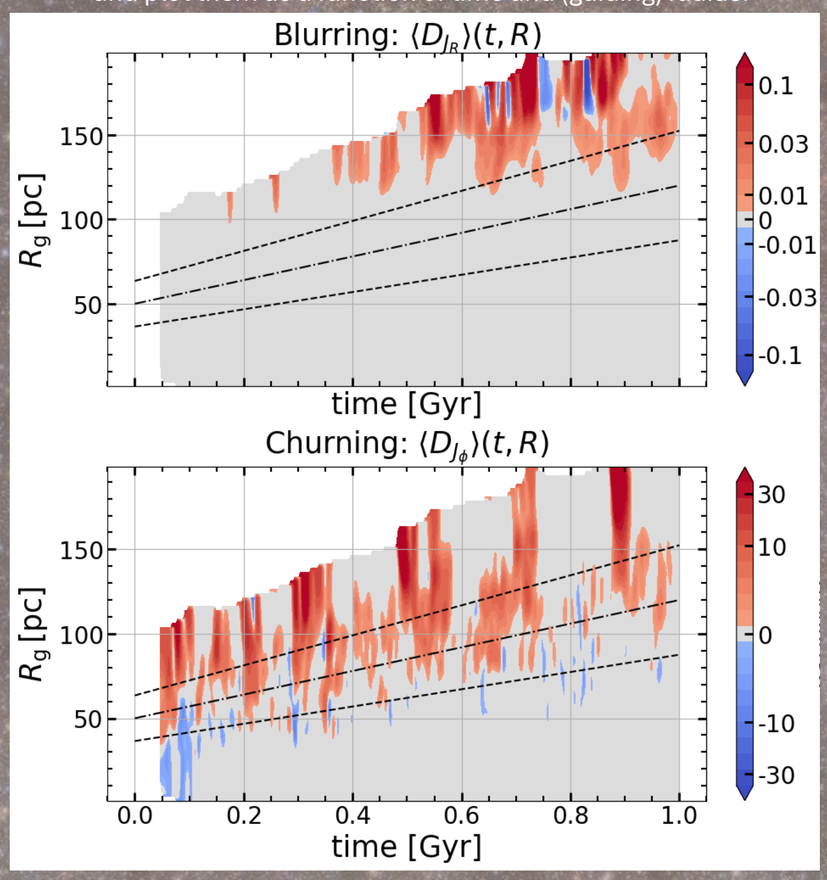
We detect churning and blurring by calculating the dispersion of J_R and L_z as a function of time.



- Blurring (red): $|\Delta J_R| > 0$. Amplitude of star's $R(t)$ changes
- Churning (blue): $|\Delta L_z| > 0$, but $|\Delta J_R| \sim 0$. Orbit radius changes while the amplitude of radial motion, $R(t)$, remains fixed

Blurring and Churning History

We measure blurring and churning coefficients D_{J_R} and D_{J_ϕ} and plot them as a function of time and (guiding) radius.

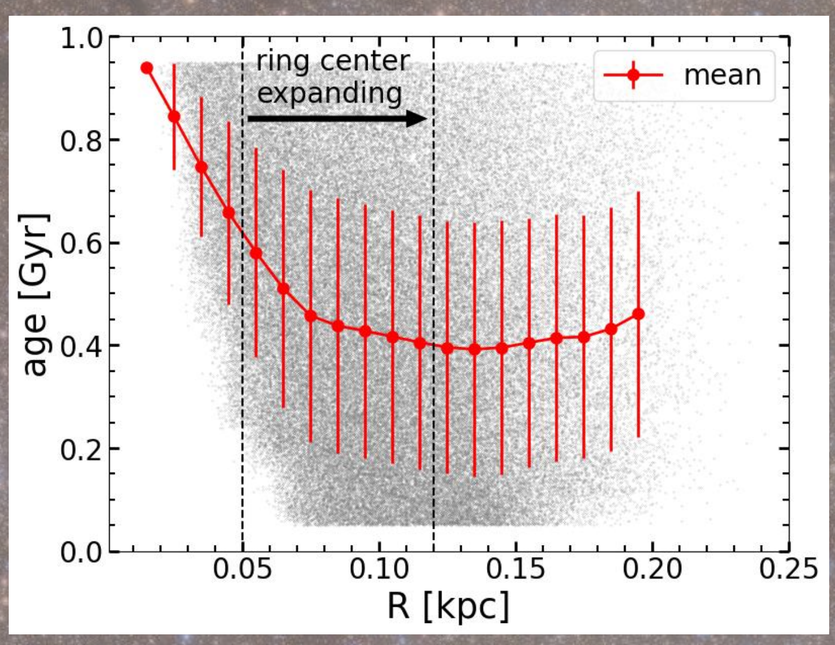


- Blurring happens at outer edge of the ring (top dashed line), and becoming more frequent at the later times, as more stars migrate outward from the ring region.
- Churning occurs in the ring region and persists over entire simulation. The net effect of churning is that stars move outward and beyond the ring's outer edge.

Stellar Age Gradient

Stellar Age at the End of the Simulation

We inject new stars into the ring region every 10 Myr as the ring expands, then examine the stellar ages as a function of radius at the end of the simulation.



- At the end of the simulation, the stellar age gradient largely preserved, especially inside the ring region.
- Early born stars migrate outward and pass through the ring, which slightly tilts up the tail of the age gradient.