Migration on the shearing sheet
Estimates for young open cluster migration

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Abstract: Using tracer particles embedded in self-gravitating shearing sheet N-body simulations, we investigate the distance in guiding center radius that stars or star clusters can migrate in a few orbital periods near the Solar neighborhood. The standard deviations of guiding center distributions and maximum migration distances depend on the Toomre or critical wavelength and the contrast in mass surface density caused by spiral structure. Comparison between our simulations and estimated guiding radii for a few young (<1Gyr) supersolar open clusters suggests that the contrast in mass surface density in the solar neighborhood has standard deviation (in the surface density distribution) divided by mean of about 1/4.

Motivations:
-Contrast in spiral structure in the Milky Way is poorly constrained by observations
-Interpretation of abundances of stars and young clusters depends on estimated migration distance from a birth radius.
-Migration is assumed to be mediated by spiral structure but the mechanism itself is not related to spiral structure properties.

Why use the shearing sheet?
-Numerical studies mostly have focused on simulations of whole galaxies. But in the shearing sheet we have more control over the spiral structure in the shearing sheet
-No coupling between spirals/bar/halo.

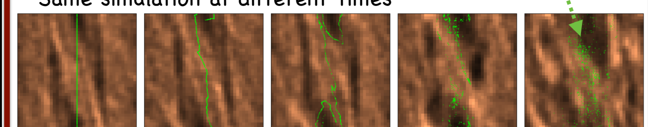
The shearing Sheet
Equations of motion depend on two parameters:
-Velocity Shear: Ω sets unit of **time**
-Epicyclic frequency: κ
oscillations in orbit about the shearing motions
We modified the SEI (Symplectic Epicycle) integrator by Rein&Tremaine+12 so that the code REBOUND would allow us to set κ / Ω for a Galactic rather than Keplerian disk

The shearing sheet is self-gravitating N-body
Fastest growing spiral structure has wavelength given by the Toomre or critical wavelength
Which also gives us a unit of **distance**

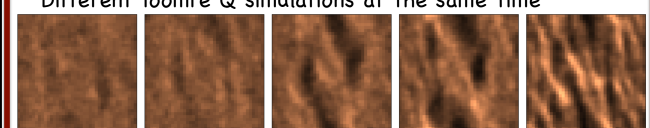
$$\lambda_{crit} \equiv \frac{4\pi^2 G\Sigma}{\kappa^2}$$

Green dots show stars initially at the same radius. After 5 rotation periods the distribution is broader. Spiral structure increases the width of the guiding radius distribution.

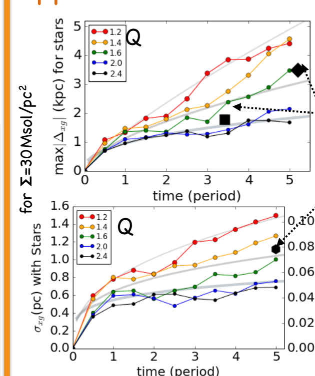
Same simulation at different times



Different Toomre Q simulations at the same time



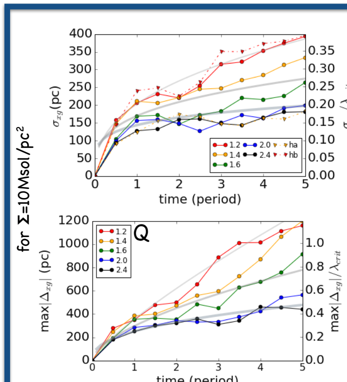
Application:



Open clusters Praesepe, Hyades and NGC 6583

Open cluster metallicity dispersion turned into a migration distance (using metallicity gradient) for age < 1Gyr old

X3 simulation is consistent! - giving us a density contrast in spiral structure!



standard deviations of migration distances at different times for different Toomre-Q disks and power law fits

maximum migration distances at different times

power law fits

$$g(\delta\rho, t) = 0.12(\delta\rho)^{\frac{1}{2}} t^{\beta}$$

density contrast in midplane

β=0.4,0.3,0.2 for standard deviation
Power law indices for max are twice that for standard deviation

Like a random walk

A diffusive model could work on such a short time if individual spiral features are uncorrelated or if patterns interfere.

Application:
-Using our shearing sheet simulations by scaling to galaxy surface density with Toomre wavelength.
-We estimate birth galactocentric radii of young (<1Gyr) metal rich open clusters, such as NGC6583, Hyades and Praesepe clusters by comparing their metallicity to that typical of their current radii and using the abundance gradient to estimate their birth radii.

Results:
-A surface density contrast of 1/4 in spiral structure, slightly higher than the COBE value by Drimmer+Spergel01, can account for current galactocentric radii of metal rich open clusters (maximal migrators) without over estimating the standard deviation in [Fe/H] of young open clusters.

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